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p. 2. Geology

MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied
to the Arts.

INAUGURAL DISCOURSE

AT THE

OPENING OF THE SCHOOL,

6TH NOVEMBER 1851.

BY

SIR HENRY T. DE LA BECHE, C.B., F.R.S.



LONDON:

PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1851.



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MUSEUM OF PRACTICAL GEOLOGY.

Geological School of Mines and of Natural History

to the British

INAUGURAL DISCOURSE

AT THE

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ON NOVEMBER 1841.

SIR HENRY T. DE LA BECHE, C.B. F.R.S.

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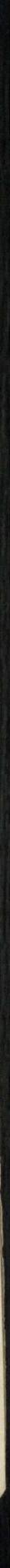
1841.

INAUGURAL DISCOURSE.

WE are this day assembled to inaugurate a system of instruction new to our country; one which does not interfere with existing institutions,—on the contrary, it may be considered as assisting several, inasmuch as while it provides for a want which they do not supply, it refers to knowledge which they teach.

That this establishment should be the means of affording instruction in a particular direction,—an instruction tending more especially to illustrate the application of Geology, and of its associated sciences, to the useful purposes of life, was early decided. In 1839, four years after the first collections were made for the Museum of Practical Geology, the sanction of the Treasury was given to lectures having that application for their object. The system of instruction we commence this day is, therefore, not founded on any new view, twelve years having elapsed since lectures of a similar general character were authorized. That these lectures have not been given has arisen from the want of a proper theatre in which to deliver them, and from the absence of other appliances not, until now, at our command.

Referring thus to the early condition of this establishment, a few words on its origin may, perhaps, not be altogether out of place. It was while (in 1835) conducting the Geological Survey, then in progress, under the Ordnance, in Cornwall, that being forcibly impressed that this survey presented an opportunity, not likely to recur, of illustrating the useful applications of Geology, I ventured to suggest to Mr. Spring Rice (now Lord Monteagle), then Chancellor of the Exchequer, that a



collection should be formed, and placed under the charge of the Office of Works, "containing specimens of the various mineral substances used for roads, in constructing public works or buildings, employed for useful purposes, or from which useful metals were extracted, and that it should be arranged with every reference to instruction;" as, by the adoption of this course, "a large amount of information which was scattered might be condensed, and those interested be enabled to judge how far our known mineral wealth might be rendered available for any undertaking they are required to direct, or may be anxious to promote, for the good or ornament of their country."

The proposal was favourably received, and its object effectually supported by Sir Francis Baring (then Secretary of the Treasury), the late Lord Bessborough (at that time Chief Commissioner of Woods and Works), and by Mr. Trenham W. Philipps, the present Secretary of the Office of Works; from the latter most material aid has always been received during the various changes of administration which have taken place during the last sixteen years. From the statesmen of the different governments who have had this establishment under their consideration since its commencement, we have, without exception, received all kindness and encouragement. As he has passed away from among us, it may be permitted me, without fear of a misconstruction of motives, to refer to the late lamented Sir Robert Peel, as one of those to whom we have been most materially indebted for our progress. He ever expressed a warm interest in our advance, was one of our frequent visitors, and not only by words, but by acts, proved the real interest he took in our success.

As soon as a locality was found for the deposit of specimens*, presents poured in in abundance, and our Cornish mining friends especially may be said, "one and all,"† to have assisted us. The collections, including models of mines and mining machinery, accumulated rapidly. A laboratory, to be alike

* In a house belonging to the Crown, in Craig's Court, Charing Cross.

† The Cornish motto.

useful to the public and the government departments, was added, and a chemist, who was also the curator*, was appointed. The collections continued to augment by the exertions of the Geological Survey, and by presents, so that there was not sufficient space for them in the house first assigned for their reception. An adjoining house, at that time the Earl Marshal's Office, was added to it. This even became insufficient, and a part of the collections was established elsewhere.† Finally, the necessity of proper accommodation became so pressing, especially after 1845, when the Geological Survey and the Museum of Practical Geology were placed under the same department‡, that—a fitting opportunity occurring—the building in which we are now assembled was erected.

We propose to instruct by means of our collections, our laboratories, our mining record office, our lectures, and the Geological Survey;—thus teaching as well in the field as in this building, and so that the pupils can become practically acquainted with mining in our various mineral districts, be able to study geology, and those of its applications requiring it, on the ground itself, and so unite, in a manner not hitherto attempted, and yet in one for which our opportunities amply provide, a sound combination of science and practice; a combination also kept steadily in view in our laboratories, and in all branches of the instruction upon which it is now purposed to enter.

It may, in the first place, be desirable to call your attention to the objects proposed by our collections. They are not intended to be mere assemblages of specimens, striking either for their brilliancy, colour, or form. In whatever department they may be found they are intended to be instructive with reference to the especial object proposed in that department, and to be employed in illustration of the teaching by lectures,

* The late Mr. Richard Phillips, F.R.S.

† In Whitehall Yard.

‡ The Chief Commissioner of Woods, Works, &c., at that time the Earl of Lincoln (the present Duke of Newcastle).

or other means adopted by those in charge of the different departments confided to them. The collections are arranged for this purpose, and so, also, that the general public, who have free admission to them during the first three days of the week, may readily understand them, by means of succinct treatises on each subject, to be had separately, and at small cost. In them the reason for the presence of the various specimens will be assigned, and it is thus hoped that much useful and valuable information may be afforded.

Let me, in the first place, briefly call your attention to the specimens of the stones applicable to architecture and engineering. This collection is based on one formed during the investigation undertaken in search of the best stone to be employed in the New Houses of Parliament, or the New Palace at Westminster, as the building is often termed. It had become evident that more care than had hitherto been taken with regard to the stone employed in our public edifices was needed, and that public buildings should not be constructed of materials so little capable of resisting atmospheric influences that they readily give way before them, their external enrichments being in some cases defaced even in a few years. We possessed an abundance of different building stones, the durability of which could be seen in various structures in different parts of the country, the quarries themselves could be studied for their capability of supply, and the cost of the transport of the stone furnished by them in different directions could be ascertained. The results of this investigation will be found in the report on the subject presented to Parliament in 1839, and our cases contain the collection then formed. Since that time all diligence has been employed to add to it, care being taken to obtain the information needed; and every specimen has an inscription upon it, showing the edifices wherein the stone has been used, so that the architect can, at a glance, see its general character, and at the same time learn where to study the effects of the atmosphere upon it. A few of our building stones have been employed in illustration of their capability for statuary; thus, excellent copies will be found of the Farnese

Hercules in Portland stone, of the Giustiniani Minerva in Huddleston dolomite, and of a bust of Antinous, as Bacchus, in Anston dolomite.*

It may, in passing, be of interest to observe that the Normans seem generally to have been very careful in their selection of the stone employed in the erection of their different edifices in this country, as is especially shown in those to which additions have afterwards been made, where we find that they had selected stone, even from comparatively considerable distances, which their successors neglected, employing a far less durable substance nearer the very edifice in which the good qualities of the material used by the Normans were abundantly apparent.

The lower hall, likewise, proves that as regards ornamental marbles, serpentines, porphyries, and granites, our land furnishes an ample supply, and that they are alike remarkable for their beauty and the facility with which they can be procured. It will be observed that they have been, when practicable, arranged so as to produce an architectural effect, thus enabling the architect, and those requiring his aid, to judge of their general appearance, and their application to the purposes thought desirable.

Still, confining our attention to the mineral substances employed by the architect or engineer, the next valuable assemblage of objects embraces the various baked materials which man for so many ages has used for the structures raised by him. This series will be found not wanting in value, and it will be our endeavour to render it instructive. The Jermyn-street front of this building, constructed with Suffolk brick and

* Reference was made to specimens of different kinds on the table, as illustrating the subject. It was briefly pointed out that building stones might be conveniently divided into, first, those cut by the tool, such as the various kinds of limestone and marble; and secondly, those pounded by the tool, such as a great variety of sandstones, porphyries, granites, and the like. Attention was called, among the former class, to the Anston stone, or dolomite (a compound of carbonate of lime and carbonate of magnesia) employed in the new Houses of Parliament, a stone similar to that used in the Norman front of Southwell church, in Nottinghamshire, the tool marks on which are nearly as fresh as when first put up.

Anston dolomite, is intended to illustrate the intermixture of two valuable materials,—the one natural, the other artificial; and it will, at some future time, be interesting to observe the relative resistance presented by each to atmospheric influences.

Our ceramic collection is extensive, and, of its kind, unique. Especial reference is made in it to the materials and forms employed in the ceramic manufactures of this country from early times. The Staffordshire series reaches as far back as 1500, and is brought up to the present time, the last additions being objects shown at the late Great Exhibition of the Industry of all Nations. This series is based on a collection made in Staffordshire by Mr. Enoch Wood, than whom no one could be more capable of selecting the best illustrations of the progress of the Staffordshire Potteries. In the hall will have been observed a tessellated pavement, designed after portions of those in a Roman villa, at Woodchester, in Gloucestershire, and formed of compressed clays, afterwards baked by a patent process, a beautiful illustration of progress in this kind of manufacture.* The other English porcelains and earthenwares, such as those of Chelsea, Derby, Plymouth, Worcester, and Swansea, are also represented by carefully selected examples, so as to illustrate their history, the circumstances connected with the materials used, and the forms adopted. I may point to the specimen showing the earliest transfer of prints to porcelain, by Dr. Wall, with the date of 1751, as exemplifying attention to the history of this branch of industry; while, as you will observe, another specimen,—a Staffordshire one, however,—shows the present state of this kind of transfer. In the first case only one colour was imprinted on the porcelain; in the second numerous colours, forming a picture.

The vitreous series will likewise be found one presenting

* Water, as employed usually in ceramic manufactures, may be regarded as a mere tool, by which the material is easily worked. It has to be removed as much as possible by evaporation, before the firing is effected. The tesserae alluded to in the text are made with materials nearly dry, only sufficiently moist to cohere when pressed. Thus they are very dense, after the heavy pressure to which they are subjected, and remain so even after baking.

much interest. This also is arranged historically, and at the same time with reference to materials, and mode of manufacture. In this series we have to pass through Venetian, Roman, Greek, Egyptian, and Assyrian glass for proper illustration. The collection has been found alike interesting to the classical student and the modern manufacturer. The analyses that have been already made of some of the glass are highly illustrative in both respects, and these researches will be further prosecuted.*

We now reach the mining collections. The metallic series is arranged so as to show the various ores of the different metals, their mode of occurrence in the earth, the methods employed in their extraction, and the means used for rendering them marketable. At this point the labours of the miner terminate, and those of the metallurgist commence. These are also fully illustrated, and the qualities of the different metals, either alone, or mingled as alloys, in their application to arts and manufactures carefully exhibited. In the department of the ores it became needful to include not only those from our colonies (attention to our colonial products being one of the objects of this institution), but also those of many foreign lands, in order to accustom our miners to kinds and modifications of them, with which they are not familiar. Those who have during many years watched the progress of our mines will be fully aware how essential this may be to their effective progress. It is well known that large sums of money have been from time to time lost from a want of this knowledge, quantities of strange ores having been washed down rivers, or into the sea, before their value was known. A recent instance may illustrate this point. Ores, regarded only as important for the copper they contained, were raised on some property of the Duke of Argyll, in Scotland. After a time the works were abandoned, as the copper found in the ores was not sufficiently abundant to pay for the cost of obtaining them, and much was thrown aside as not worth dressing. The Duke,

* For example, the Roman glass, found near Naples, seems to have a common character, and to be formed, as chief ingredients, of the silicates of lime and soda, the latter probably derived from the natron lakes of Egypt.

impressed with a certain character in the ores, brought specimens to this institution for analysis, when it was found that they contained 11 per cent. of nickel, a valuable metal, and, as you are aware, extensively employed at this time in different alloys, such as those known as German silver. Other portions have been found still richer in this metal, and the ore thrown away and dispersed has been valued at from 40*l.* to 50*l.* per ton. It may be added, that even after this ore was thus found to contain nickel, it was stated, from an assay elsewhere, not to afford this metal; so little diffused is effective metallurgical knowledge in this land.*

Both the composition of ores, and their mode of occurrence, involve questions of high scientific interest, bearing upon practical applications of great importance. Let us for a moment regard the accompanying diagram†, representing a proportional and sectional view of our earth, with the atmosphere, and a hundred miles beneath the surface of the sea; of the matter really at that depth we know nothing, but it is convenient, as showing that if we did possess that knowledge, the portion of the earth then known would be exceedingly small. As far as we are acquainted with the rocks upon the surface of our spheroid, they are formed of various oxides of different substances, supposed simple. The exceptions, as regards the general volume they occupy, are insignificant. In certain cracks, fissures, or other cavities in this mass of oxides, we find matter under other conditions, derived probably from beneath, and, as it were, affording something of an insight into substances there more abundantly occurring. There may be secondary conditions of the same compounds, but still the inference remains that these fissures and other cavities may afford, by careful study, information in the direction mentioned, and it is important to remember that while the mean density of the surface of the earth is taken at 2.6, that of the whole mass is inferred to be

* Even within these few days a case has occurred in Devonshire where a field wall was constructed of grey copper ore, and the breaking of a gate post led to the knowledge of the fact. This happened in a mining district.

† Referring to one exhibited.

4.39, pointing to heavier matter inwards, whatever views we may entertain of the diminution of density produced by heat in the interior.

At first sight the practical value of such an inquiry may appear very remote. It is, however, like all investigations of the highest science, one which may bear fruit if properly followed out. We have, in the first place, to couple it with the observed modes of occurrence of the ores of the metals in fissures and other cavities, and carefully study why it happens that given conditions produce given results; as, for example, why is it, that in Derbyshire,* where the same fissures traverse different rocks, only certain of them have, as it were, permitted the accumulation of lead ores near them, while others, as a general fact, have repulsed them. Such facts are not new to the miner; he is familiar, in different districts and lands, with the modifications and changes observed in the assemblages of ores of all kinds in contact with various rocks in the same range of fissures. The cause of these facts is an object of science, and already progress has been made; when found it becomes a guide of the highest importance to the practical miner.

Our collections of the mode of occurrence of the ores are very extensive, and great care is taken to make them effectively instructive. As to the methods of their extraction, models and drawings of various kinds show not only the different machines used for draining mines, but also the mode of raising the ores. Great attention is given to this subject. So also with respect to the dressing of the ores, the like regard to proper illustration is paid.

The metallurgical series contains examples as well of foreign as of our own methods of reducing the metals. Our cases are full of objects of interest in this department, as well as of illustrations of the uses of the metals, and of their compounds or alloys in arts and manufactures, including an electrotypes series of much interest. The ductility of copper, as shown in the specimens on the table, and as formed into the elegant vessels

* Pointing to a diagram on the wall.

exhibited, will illustrate the manner in which this subject is treated, as will also the statuettes before you, formed of bronze composed of the alloy which our analyses have shown to be that most effective for casting figures, and which is, at the same time, one that the Greeks and Romans seem to have adopted.

Quitting the metalliferous series, we may mention that the methods of working coal, due regard being had to that important object, the ventilation of collieries, receive ample attention. Indeed we endeavour to be as complete as possible in all things illustrative of the working of mines, of whatever kind these may be, and are not neglectful of a variety of mineral products, such as rock salt, sulphur, alum, plumbago, and the like, which it would be out of place further to notice.

Our very important and valuable palæontological collection should nevertheless be specified, since it may be regarded as the most perfect of its kind: it is the joint result of the labours of the Geological Survey, and of a mass of presents, even of whole private collections. Of the value of such collections it would be superfluous now to insist, since, as you are aware, all mining schools strive to possess them in as extended a form as possible; those who desire and support such schools being fully sensible of their important bearing on geological investigations, and consequently on the practical applications of geology. Did time permit, it would be easy to show how many mistakes have been made, especially in seeking for coal; thousands have been thrown away in a vain search for that which a very moderate acquaintance with palæontology would have prevented.

Donations to our collections have been again mentioned. It may be here observed that the larger portion of them are composed of presents, showing, as we hope, that the public are not dissatisfied with our endeavours to be useful. From the Great Exhibition alone the donations we have received must already have reached a value of not less than 3,000*l.*, and these presents have not yet ceased.

Passing over the series illustrating the formation of rocks at different geological times, and of the changes which have taken place in them since their deposit, many of which have practical bearings,—as, for example, the roofing slates formed by the

action which has been termed *cleavage*, and which so distinguish themselves for durability from those obtained by the simple lamination of rocks, corresponding with the planes of their deposit, we come to the Mining Record Office.

This office was established in connexion with the Museum of Practical Geology in 1840. It was so for the purpose of collecting information respecting the distribution and produce of our mines,—and for procuring plans and sections not only of modern workings but also of abandoned mines,—the last especially important, as being the means of saving life, or the erroneous outlay of capital, by preventing new works from being carried on in wrong directions. It is but right to remark that we have always received hearty co-operation from the mining interest in carrying out the objects of this office. To illustrate the value of the plans and sections of abandoned mines, let us select from those on the wall before us a section of Wheal Alfred, Cornwall. It had been stated that the working of this mine, at one time a most prosperous one (having afforded a profit of 140,000*l.*), had ceased on account of much water, which the engines of the time were supposed not equal to raise. A company was about to be formed, when it was suggested that documents known to be in our Record Office should be examined. The section before you at once pointed out, by the prices of work entered upon it, that the mine had been abandoned for its poverty, the undertaking was in consequence dropped, and a large useless outlay of money avoided. The section is the present of Mr. John Taylor, to whom the Mining Record Office is most especially indebted for numerous and important documents of the like kind.

From the aid also afforded by those interested we are gradually acquiring more real information respecting the products of our mines than has been hitherto procured; a subject alike important for the miner and the public. The copper ores raised have long been well ascertained, and the same may be said for the tin, even now that the “tin coinage” of Cornwall and Devon has ceased. We have been enabled to produce lead returns during the last four years, of an accuracy not before known. We are now proceeding with the other metals and

coal, and hope, at no distant date, to produce effective returns of these also.

The laboratories, one for general chemistry, the other for metallurgy, and their bearing upon a School of Mines and of Science applied to the Arts, may be said to speak for themselves; their usefulness and importance are evident. A special metallurgical laboratory has not been previously attached to any place of instruction in the country. With regard to the work executed at these laboratories for the public service, we may point, as one of the last of our endeavours to be useful, to the inquiry undertaken for the Admiralty as to the coals of this country best suited to the steam navy, three reports on which, completing the investigation, have been presented to Parliament. It will be obvious that to obtain the greatest amount of locomotive power from the smallest volume of fuel, and to avoid the evolution of smoke, are points of no slight importance for our steam navy.

As it is contemplated that our students should avail themselves of the Geological Survey for field instruction, including actual mining, it may be desirable, perhaps, to call your attention to certain of the maps and sections constructed by that survey, and now before you, inasmuch as, while they refer to geology as a science, they are at the same time available for its industrial applications. Thus you will observe that all mineral veins and the outcrops of coal-beds are inserted on these maps, as well as the boundaries of the various rocks, and with the exactitude required. The sections, in like manner, show the mode of occurrence of the coal and ironstone beds in certain districts, and the mineral veins in others.

A point of much interest, both in its scientific and practical bearing, is now engaging the attention of the Survey in central England, namely, the probable depths and chances of obtaining coal beneath the red sandstones and marls there so abundant. There is reason to consider that, notwithstanding the many difficulties with which the subject is surrounded, very considerable advance has been made in this direction.

That the applications of such a survey are not confined to mining, you need scarcely be reminded; its aid to agriculture

and engineering are equally important. Our every-day's experience along coasts shows us how needful it is that the engineer should, as well as the geologist, study them. Let us, for example, consider this cove*,—there are hundreds such as it to be found on our coasts. The mode in which it is silted up is apparent to you, and yet many an artificial cove has been constructed, at great cost and loss, which was as certain to be filled up by silt and sand as this has been and must be. No doubt there are conditions where the silting up may be so small as to be comparatively unimportant, but the probability of this condition requires the study pointed out. While on this subject, let me also briefly call your attention to the silting up of estuaries. Those who are engaged on the Geological Survey have often to consider it both with reference to the mode of deposit of certain rocks, and to the changes effected by it at the present day. The plan before you shows an estuary with the boundaries of high and low water, a spit of shingles running in front of part of the estuary, separating it from the sea, and the comparatively narrow entrance for the ingress and egress of the tide. The whole is the result of the balance of certain conditions by which the channel from the sea to the estuary is kept clear, and vessels of a certain class can enter and depart. The body of water entering and passing out is important; and yet what do we often find done, and done too by Act of Parliament? The body of water entering, and consequently passing out, is diminished for the purpose of *reclaiming*, as it is termed, certain mud-banks, often extensive; thousands of tons of water are thus sometimes cut off from performing the work by which they aided in keeping the channel to the sea clear; the bottom of the channel rises, and the port is damaged. No doubt the mudbank may be converted into fertile land, but at what loss! The natural causes for deteriorating estuary harbours are often bad enough, but why artificially strive to injure them? Other examples of the application of geology to engineering and the useful purposes of life generally might be readily

* Pointing to section on the wall.

adduced; these, however, may suffice to illustrate their importance.

Although the raw mineral produce of Great Britain and Ireland is valued at 24,000,000*l.* per annum, or about four ninths of that of all Europe, including these islands (the coal estimated at the pit mouth, the iron in the pig, and so on), there existed until now no means in this country for affording needful instruction to those who thus raise so large an amount of mineral matter, to be afterwards employed in affording occupation to an additional and large part of our population; all was left to chance, and the result is well known. Many who could afford it go to other lands to study in the mining schools provided by their governments; some fight through their difficulties at home, becoming valuable and useful men; while the mass of our miners remain uninstructed, except so far as they can pick up practical information from each other in the mines, seldom being conversant but with such things as they can find in very limited districts, little aware of what others may be doing in their own calling elsewhere. The diagram exhibited will show you the relative proportions of the annual mineral produce of the different European countries,* in nearly all of which, except Great Britain, mining schools are established, those states being fully aware of the effective researches they promote, and the waste of money they prevent. Are our miners less deserving of attention than those of other lands, or are they supposed so dull and disinclined to knowledge as not to be capable of profiting, as well as the miners of other nations, by instruction? Let those who thus believe visit our mining districts, espe-

* This diagram represented the mineral produce of the different European states by proportional lines. This produce is usually estimated as follows:—

Great Britain	-	-	-	1	Hartz	-	-	-	-	$\frac{1}{12}$
Russia and Poland	-	-	-	$\frac{2}{7}$	Tuscany	-	-	-	-	$\frac{1}{31}$
France	-	-	-	$\frac{1}{4}$	Bavaria	-	-	-	-	$\frac{1}{33}$
Austria	-	-	-	$\frac{2}{13}$	Saxony	-	-	-	-	$\frac{1}{34}$
Spain	-	-	-	$\frac{1}{8}$	Piedmont and Savoy	-	-	-	-	$\frac{1}{38}$
Prussia	-	-	-	$\frac{1}{5}$	Denmark	-	-	-	-	$\frac{1}{40}$
Sweden	-	-	-	$\frac{2}{17}$	Norway	-	-	-	-	$\frac{1}{55}$

cially such as are metalliferous, where the miner has so often to gain his daily bread by the exercise of his judgment, and they will speedily be undeceived. They will find men as able and willing to profit by instruction as elsewhere in our land. They will see many with powerful minds who have risen from amid all their difficulties, adding continually and greatly to our stock of practical knowledge, but who yet would evidently have accomplished far more, if, in their early day, they had possessed the advantage of starting with the knowledge of the time applicable to their pursuits. It is to be deplored that so much of the mass of important facts known to such men has been lost from the want of a system by which it could have been preserved for classification and use in further advance. Too much has perished with the remarkable men who have from time to time appeared in our mineral districts.

Seeing the large proportion of the mineral wealth of Europe furnished by the British Islands, it might, perhaps, be inferred from a superficial view of the subject, that a mining school, such as we propose opening this day, is useless. Very slight investigation will soon place this matter in its true light. The natural advantages, and especially the mode of occurrence and abundance of coal and of iron,—the cheapness and good qualities of which enable so many other industries to flourish,—are great in our land; iron and coal can be easily procured, worked, and retained for home use or exported, as may be thought advisable. These advantages are by no means possessed in like manner by other countries in Europe. Far from it; indeed, in several it is only by a most careful application of science and practice, and by seizing every discovery that can be turned to account, that profit can be effected. If the same indifference to general knowledge there existed as is permitted among us, the mineral produce of many of these states would be greatly diminished, and in some cases the mining in certain districts might even, to a great extent, be suspended, until new discoveries in science might enable successful operations to be carried on. For example, within the last three years, in Reichenstein, Silesia, where, after remaining idle for five centuries, a new method of obtaining gold from certain poor auriferous ores, by Professor Plattner,

enabled these mines to be again worked, and with considerable profit.

Looking at our mineral produce, the great and chief mass is composed of our coal and iron. We raise the largest amount of both among the nations of the world; not that we possess the largest amount of coal in any land,—in this respect the United States of America far surpass us. The working of it, however, remains to be developed by them. The more need, therefore, that by skill on our part, and by not neglecting the application of knowledge which may bear upon it, we should not permit our advantages to escape. As regards fuel, what would man be without his power to use it and produce fire? Remove this power, and what happens? How far could he range towards the colder regions of the earth, either as regards elevation in the atmosphere, or towards the poles? He must be a fire-making before he can be the cooking animal, which he is sometimes termed. Taken with iron, the great metal of civilization, his fire-making power is rendered immensely advantageous for his advance and well-being. Cheap heat and cheap iron are, therefore, among his important wants. While this country possesses the power to produce both, let not that power be wasted,—let science and practice be so combined, that the largest amount of both may be secured, and the future be regarded as well as the present.

The amount of coal annually raised in Great Britain (comparatively little is supplied by Ireland) is estimated at more than 35,000,000 tons. It probably much exceeds this amount; but taking that number of tons, 2,800,000 tons* being exported, 32,200,000 tons remain for household consumption, and for application to our various industries. London alone consumes nearly 3,500,000 tons of coal. No wonder we have a smoky metropolis.

With regard to iron, Great Britain has made remarkable progress within the last century. In 1750, only 30,000 tons of that metal were raised in it. In 1850, 2,250,000 tons of

* The quantity of coals, culm, and cinders exported in 1849 was 2,827,979 tons.

iron were produced. It is somewhat difficult, by means of official returns, to obtain the exact equivalent in tons of pig-iron exported, but we find the value of the iron export in 1849, including pig and bar iron, iron wire, and various kinds of wrought iron, taken at 4,245,049 $\text{\textsterling}$.^{*} Iron, therefore, of many millions in value remains for our home consumption, applied in various ways to our national industry. Tin should not be omitted as among our important British metals, seeing that it is raised to the amount of about 500,000 $\text{\textsterling}$. annually; neither should our copper be forgotten, since that of Cornwall and Devon alone may be valued at nearly 900,000 $\text{\textsterling}$. annually. With regard to the copper and tin of that district, (British tin being alone found there,) the former yields one-third, and the latter nine-tenths of the whole supply from the remainder of the British islands and all the other countries of Europe. As to tin, the quantity taken from Cornwall and Devon from the time of the Phœnicians must have been enormous, seeing that until of late years it seems to have supplied nearly the whole of the European demand.

It has been mentioned that no institution existed, other than that we now propose to establish, in which the instruction so beneficial to our miners could be afforded. It, however, should not be forgotten that Sir Charles Lemon, ever alive to the progress and well-being of his native county, Cornwall, did, in 1838, establish at his own cost a mining school in it, being desirous of showing the importance of such an establishment. He continued this school for two or three years, and offered to place a considerable sum of money—10,000 $\text{\textsterling}$.—at the disposal of the county, if it would add the like sum, to found a proper school of mines in Cornwall. Circumstances at the time prevented this important object from being carried out. There would, however, appear to be a movement in that district in the direction of such a school. Let us hope that it will continue, and be productive of a fitting establishment of the kind. There are also indications of the like movements in other mineral districts.

^{*} This does not include steam engine machinery and mill work, the value of which, exported in 1849, is given as 709,071 $\text{\textsterling}$.

prominently, as is shown by the division of labour which has, of late, so much occupied the attention of its cultivators. Thus we have seen it requiring, and obtaining, the assistance of the mathematician, the astronomer, the physicist, the mechanician, the chemist, the mineralogist, the zoologist, and the botanist.

In applying such a branch of knowledge, it therefore, becomes important to view it as of a mixed kind requiring a corresponding system of instruction; its applications also requiring teaching in given directions, so as to embrace the conditions arising from the applications themselves. Hence the instruction proposed to be carried out at this institution is divided into various heads, so as to have reference not only to the miner and manufacturer, but also to the agriculturist, the architect, and the engineer, and so that the subjects taught should also be viewed in connexion with those arts to which they may be applicable.

In these days, when ocean steamers, railways, and electric telegraphs are transporting man, or his thought, from region to region, with a certainty and despatch not deemed probable even a few years since, and when a great Industrial Exhibition has just closed after a most brilliant career—an Exhibition which could not have existed without these and similar aids to the progress of mankind, it might appear superfluous to point to any applications, even those of the highest sciences, as contributing to the well-being of our kind. We still, however, too frequently hear of practical knowledge as if in a certain sense opposed to a scientific method of accounting for it, and as if experience, without that advantage, were more trustworthy than the like experience with it. Such may not, certainly, be the actual expressions; but the usual reasoning adopted, nevertheless, too frequently amounts to the same view.

Let it not for a moment, however, be inferred that we do not regard practical knowledge as of the highest importance, even in cases where those possessing it may not also possess the power of satisfactorily analysing it. Facts brought to light by practice are to general progress that which experiments are to experimental philosophy,—they have to be properly explained by the best methods at command, after they have been satisfactorily proved to be facts; a matter of no slight impor-

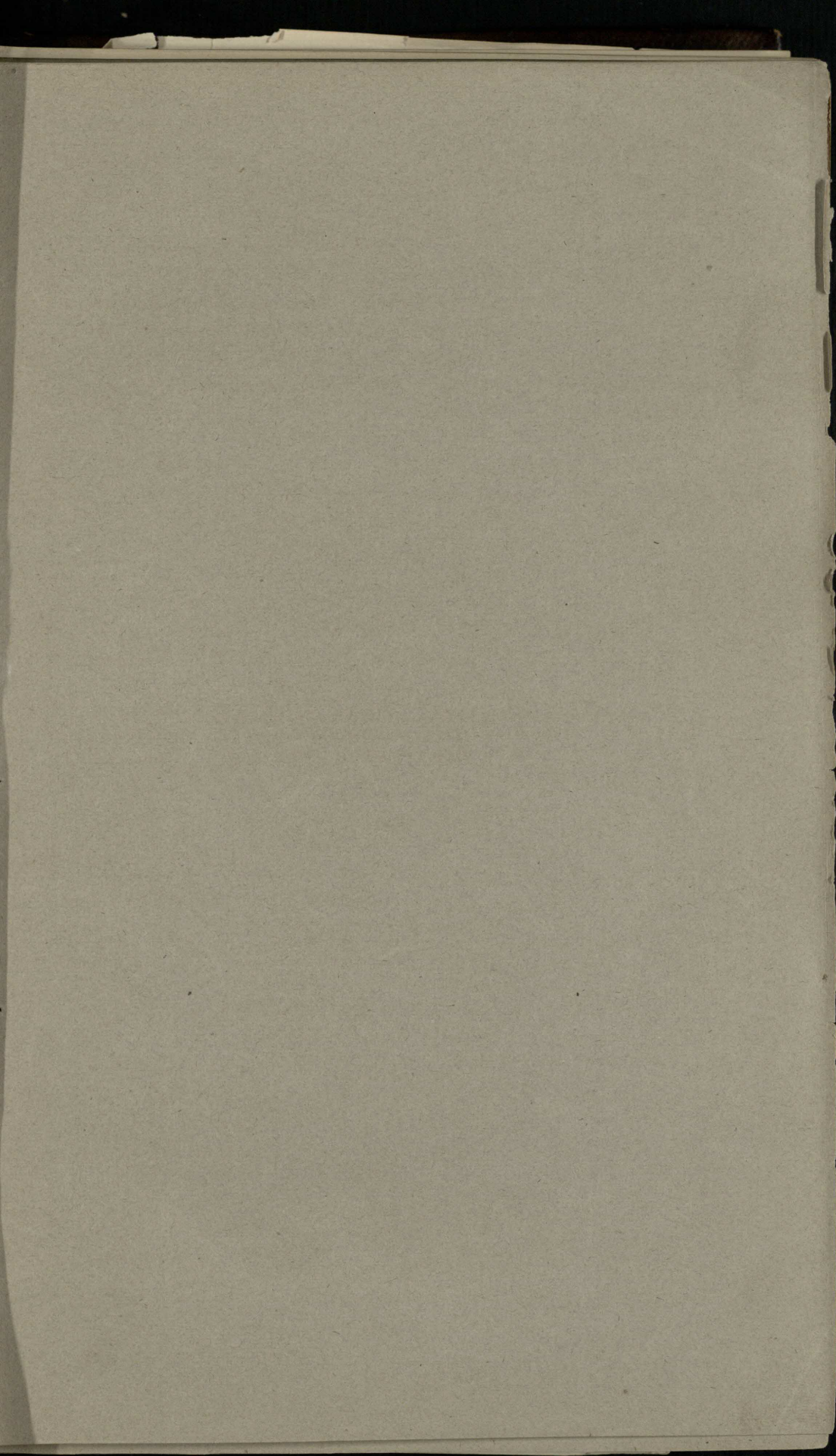
tance, seeing that so many things, so termed, are not such, We only desire that all interested should have the power to discriminate between sound and unsound views, so far as existing knowledge may be available,—taking all care not to neglect or depreciate the information afforded by those whose opportunities may not have sufficiently advanced their power to analyse and extend it. We should recollect how rapidly the science of our time has increased among the most instructed, and with it the power of its extension and application in directions not dreamt of by our forefathers. As some reason, right or wrong, is sure to be assigned for every practice, it is most important that those connected with it should possess the existing knowledge upon which it rests. It becomes a national duty to assist in collecting that knowledge for them, especially when widely scattered. For the purposes contemplated at this establishment, facts, bearing upon the teaching proposed, are to be sought far and wide, among various other nations as well as in our own. That there is an increasing feeling among those most interested, that successfully to apply a science requires both a knowledge of that science and of the subject to which it is to be applied, and that wherever there is a want for promoting the combined information it should be supplied, our every day experience shows.

Those whose duties or inclinations take them among our industrial population can scarcely fail to observe how much the term *practical* is becoming appreciated in its true sense. Indeed, the difficulties which the instructed in that population have to contend with from the uninstructed can scarcely otherwise than lead to correct views on this head. It is the duty of all to assist in affording to those whose minds are alive to every application of knowledge the power to acquire that which they are desirous of applying, so that they may possess the means of analysing their practice successfully for general progress and the public good. The more real knowledge is diffused, the more will effective practice be increased. Science and practice are not antagonistic, they are mutual aids. The one advances with the other. Civilization advances science, viewed in all its strictness and height; and science, by its applications,

advances civilization. Steadily bearing in mind these truths,—as we conceive them to be,—it will be our earnest endeavour at this institution to be useful, as far as our powers and abilities may permit, in promoting the progress of those for whom our teaching has especial reference; trusting, at the same time, to supply a national want, and, by so doing, assist in advancing the general good of our country.

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MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied
to the Arts.

ON THE

IMPORTANCE OF CULTIVATING HABITS OF OBSERVATION.

(BEING THE INTRODUCTORY LECTURE TO THE COURSE ON
MECHANICAL SCIENCE, SESSION 1851—1852.)

By ROBERT HUNT,

KEEPER OF MINING RECORDS.



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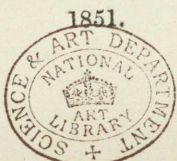
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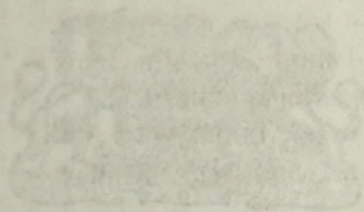
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IN studying the phenomena of human progress we discover much that is of the highest interest to the philosopher, as illustrating the manner in which the powers of mind have been turned to the investigation of the works of creation, and displaying, at the same time, the beautiful reaction of each discovered truth in the improvement of man's social state.

The past must ever be the teacher of the present, and a bright or clouded future is entirely dependent upon our appreciation of its teachings.

Man, gifted with exalted powers, is the inhabitant of a most wonderfully constituted world, and according to the industry with which he exerts his reason he becomes the possessor of its wealth.

The animal necessities of the race are the primary excitors of the reasoning powers, and we find uncultivated man exerting his intelligence only to snare and destroy beasts, to furnish him flesh for food, or skins to shelter him from atmospheric changes. From this state he advances to a pastoral one, and studies to lessen his toils by domesticating animals, and thus escape from the perils and uncertainty of the chase. In the repose of a shepherd's life habits of contemplation appear to have had their earliest birth, and the phenomena of nature to have interested the human mind. Attention once awakened to the ever-changing, still recurring operations of organic life,—to the mysteries of alternating light and darkness,—the gradual and regular passage of the seasons,—the beauty of the stellar vault, and the meteoric displays which are for ever occurring in the earth's atmosphere,—an imperfect science slowly crept into existence, the full development of which was long retarded

by the misty superstition with which man invested all things that he could not comprehend.

Without attempting to analyze the psychological progress of man in his study of the exacter sciences, which will, however, be found to be dependent upon his habit of methodizing ideas, we may, by confining our attention to the simple discovery of natural truths, see that all advancement has been the result of *experience*.

Facts frequently returning have at length solicited attention, and thus is cultivated habits of *observation*. By close attention new features are discovered in the phenomena; results which had long escaped casual and heedless glances are developed, and the mind is thus led up to the inquiry after the exciting cause. True science now begins, and the evidences of *experiment* are sought. A philosophical method is eventually developed, and its operations are displayed in the careful classification of observed phenomena, in the consideration of which the human mind necessarily demands the assistance of *theory*; and as this is constructed in accordance with true observations, or in obedience to the exuberent thoughts of an imaginative mind, is the discovery of truth accelerated or retarded.

To the record of careful observation we owe the first or initiative idea of every truth. The earliest duty, therefore, of every teacher is to train and educate the mind in habits of close and exact observation.

Man cannot create, but he is endowed with powers by which he may examine everything which is created, and by combination produce results which are to the uninitiated, but little short of a creation, when applied to the amelioration of some of the necessities of mankind. Human intelligence has bound the physical forces to do man service, and all the great applications of science may be referred to in proof of the position that human progress is directly dependent upon careful observation, and the habit of recording, in a systematic manner, the facts which have been thus developed to the mind.

The history of every science affords examples of this; the devious and uncertain wanderings of the astrologer, the alchemist, and the cosmogonist exhibit the severe struggles of truth

through the mazes of imagination; while the advancement of astronomy, of chemistry, and geology may be appealed to as expressive of the advantages of working diligently with a system of observation for our guide, and waiting patiently for the development of the truth.

It has been said, and said too by a great authority, that in experimental science we owe much to accident. Depend upon it, however, as a general rule, there are no accidents in science. It is true that often in the progress of an investigation an unexpected circumstance gives rise to a new train of inquiries; new ideas are the result, and discoveries the consequence. If that which may be regarded as an accident does not generate a clear idea, and generalize a correct system of inductive search, it remains a valueless fact.

Thales, of Miletus, observed, that amber being rubbed attracted light bodies. Here was a fact, probably of accidental discovery, which failed to produce a definite idea; and remember, nearly 2000 years passed away before man detected the truth that the *electron* of the Greek philosopher was a source of the all-diffusive agency, electricity. Galvani noted the convulsive movements of frogs, when the moist surface of their bodies was in contact with two metals of unequal affinity for oxygen; this generated a correct idea in the mind of Volta. Step by step induction has followed in this path, and we have, within a period of sixty years, the discovery applied to metallurgical processes of great utility, and to the valuable one of firing simultaneously any number of holes in the operation of blasting rocks, by which the sinking of shafts and the driving of levels in our mines are carried on with great rapidity and much economy. Following on the same tract Ørsted proved that a copper wire under the influence of an electric current became a temporary magnet. It was soon shown that an iron bar placed within an helix of such wire acquired most powerful magnetic properties; and within twenty years this knowledge has been applied to measure the tread of time, and to be the winged messenger of human thought, surpassing beyond all limits the speed of the "tricksy Ariel," and leaving the hurrying tempest like a laggard in its path. These facts were adduced by my colleague, Dr.

Playfair, in support of his arguments when discoursing of the value of abstract science; but as it will be my duty to show you in the progress of my course the experimental evidence to which I have now referred, I have not hesitated about repeating the striking illustration which these physical forces lend to the position I maintain. I cannot allow the present opportunity to pass without drawing attention to the evidence afforded by the attempts which have been made to apply the electrical element as an illuminating and mechanical power, of the danger of attempting to do so before we have acquired an accurate knowledge of all the phenomena which are involved in the conditions of the application. In the arc of light produced between the poles of a powerful voltaic battery we obtain the most vivid illumination which can be produced by artificial means. Ingenious mechanical contrivances have been devised to render the distance uniform between the charcoal points, which form the polar terminations of the wires, and thus to give steadiness to the electrical light, but since there is a constant transfer of the solid element from one pole to the other, the required steadiness has not yet been obtained. The question of the economy of this application, even if successful, may be conveniently embraced in connexion with the consideration of the application of electro-magnetism as a motive power. It has been stated, and is indeed now well known, that we can obtain an enormous attracting and repelling force by the agency of electro-magnets. In some cases magnets have been placed upon the periphery of a wheel, while others have been fixed upon a firm circle surrounding it. By mechanical contrivances the polar disposition of the magnets has been rapidly changed. The consequence of this is the exercise of an attracting and repelling power, by which the wheel is driven swiftly round. Another form of construction, offering some advantages, is a cylinder, around which clothed copper wire has been coiled, thus forming a hollow magnet, into which another solid magnet representing a piston is drawn, and from which, by changing the poles, it is afterwards repelled. By this means a long stroke is obtained, and by a crank any kind of machinery set in motion.

The first difficulty which has to be encountered here, is the very great rapidity with which the power diminishes through space. An electro-magnet which will sustain 220 pounds when the armature is in contact with its poles, exerts an attractive force of $40\frac{1}{2}$ pounds when the armature is at a distance of one fiftieth of an inch only. Now you will perceive that under any of the arrangements which have been adopted the moving and the fixed magnets could not be brought nearer together than the fiftieth of an inch; hence there is an immediate loss of one fifth part of the power we have produced.

The second difficulty to which I had the satisfaction of first directing attention in this country, although I have since been informed that it had been detected by Jacobi, is, that the moment the magnets begin to move there is a temporary loss of power, or, perhaps it would be more correct to say, there is a development of an opposing force, by which the mechanical power is again considerably diminished, and the greater the speed with which the magnets move, the more rapidly does this decline. The report made by order of the American government on Professor Page's electro-magnetic engine directs attention to this fact, which the reporting engineers were not able to explain. Mr. Hjorth, the most recent inventor and patentee of electro-magnetic engines, after the publication of my paper, observed the influence of these induced currents, and with a view to economy endeavoured to employ them in effecting the precipitation of the zinc, from the sulphate of zinc formed in the voltaic battery employed, but without success. Such are the difficulties which at present stand in the way of applying electricity as a motive power. It may be said, that these resolve themselves into questions of economy. Granted. The whole of this question I have investigated with the closest care, and the result is, that a grain of coal consumed in the boiler of a Cornish steam engine will lift 143 pounds one foot high, whereas one grain of zinc consumed in the voltaic battery will lift but 80 pounds through the same space. Now the cost of zinc is $216d.$ per cwt., while the cost of coal is but $9d.$ per cwt. It will be my duty to show and explain early in the present course of lectures that the

development of power, of whatever kind, is always accompanied by a change in the form of matter somewhere. To obtain a given amount of exertion from a horse we learn that it is necessary to give him a larger quantity of food than when he is at rest. If we desire to impel a locomotive engine at a high velocity we are compelled to supply an increased quantity of fuel, that steam may be generated with greater rapidity. We know of no development of force, whether heat, light, electricity, or muscular power, without such a change in the form of matter as amounts, to us, to its destruction. Muscle is consumed in every exertion of animal strength. Carbon and hydrogen in like manner are burnt in producing our artificial lights, either as gas, oil, wax, or tallow, and also in the production of heat, whether in our domestic fires, the furnaces of our manufactories, or the boilers of our steam engines. We evoke electricity by several methods of disturbance, but we have only now to consider that means of development which depends upon chemical action. Although we employ magnetic force, this is dependent on the power which is produced in the voltaic battery, and the zinc or any other element which may be employed is converted into some new form. Zinc, for example, is changed by the action of sulphuric acid in the battery into sulphate of zinc; and the advocates of the application of electricity as an illuminating or moving agent on the ground of economy state, and truly state, that the salt may be reduced and the metal revived. From my investigations of the whole question I feel assured that I state a truth in saying the coal employed in reproducing the metal would afford as much light, heat, or mechanical power as that obtained by the destruction of the metal in the first instance in the battery.

Let me not be misunderstood. In the present state of our knowledge I deem it hazardous to attempt to apply electro-magnetism instead of steam. Notwithstanding the rapid discoveries made in every branch of electrical research, and the great power which we can command in our voltaic arrangements, it must not be forgotten that the quantity of electricity obtained is exceedingly small in comparison with the quantity which exists in the elements constituting the voltaic battery. Dr. Faraday,

whose experimental researches in electricity must be regarded as the finest example of inductive investigation to be found in the annals of British science, and the most perfect exemplification of the philosophy of Bacon to which the student in physics can be referred, has proved that a single drop of water holds imprisoned in its liquid chains a quantity of electricity which equals that contained in an ordinary thunder-cloud. In every form of the voltaic battery a very large quantity of electricity is lost in passing from the liquid to the solid element, and the contrary ; so that in overcoming the resistance nearly three fourths of the power is consumed.

Allow me to give another example of the value of close observation in connexion with magnetism. Dr. Faraday was the discoverer of the fact, that when a hollow helix of copper wire containing a core of soft iron was moved in front of or near the poles of a permanent steel magnet, electricity was evolved, and all the results of voltaism readily produced. Hence the formation of magneto-electrical machines ; and in the great electro-plating establishments of Birmingham we may see the process carried on by the current thus generated by the revolution of coils of copper wire placed on an iron armature near the poles of an ordinary steel magnet.

To the true philosopher everything, howsoever insignificant to ordinary minds, is felt to deserve attention, and the minutest phenomena claim the most accurate study. A body falls to the ground,—a drop of water hanging from a rod, or resting on a leaf, assumes a spherical form. Nature is asked, Why is this ? and the answer is the discovery of the law of gravitation, by which power each planet is retained in its orbital path around the sun, and the entire solar system, held as completely in union as the particles of the water-drop, moved through space under the influence of a gravitating force resident in some far distant and probably unseen star. Reflection on the discovery of the planet Neptune must lead to the conviction of the truth of the Newtonian law of gravitation.

Up to the year 1804 the planet Uranus moved in its orbit without any appearance of disturbing influences ; but at that period an accelerated motion became evident, and this con-

tinued until 1822, when the planet's rate of progress was retarded, and this has continued to the present time. It was felt that according to the law of planetary disturbance, the gravitating action of Jupiter and Saturn not being sufficient to explain the perturbations, it was probable that a mass of matter exterior to our known system was the exciting cause. In this state of the question the following problem became the subject of investigation to Mr. Adams, in England, and M. Leverrier, in France, unknown to one another:—"Given the disturbances to find the orbit, and place in that orbit, of the disturbing planet." These geometers arrived at conclusions differing from each other only $3^{\circ} 19'$; and M. Leverrier having announced to Dr. Galle, of the Royal Observatory of Berlin, the position in which a new planet,—the disturbing cause,—should be found according to his calculation; on the very night of the day on which the letter was received the astronomer of Berlin discovered the planet Neptune in a point of space differing only $47'$ from the mean of the two calculations. The planet Neptune, like the old planet Saturn, is surrounded by a ring. Allow me for one moment to direct attention to some experiments by Plateau on the condition of bodies relieved from the influence of gravitation, which appear to show that the remarkable phenomena of these two planets, with their luminous rings, are due to the influence of motion exerted under peculiar conditions. If oil is dropped upon water it swims; if upon alcohol it sinks; but if we make a careful combination of water and alcohol we obtain a fluid of the same specific gravity as the oil, and the globule of oil will swim in the very centre of the fluid, a perfect sphere. If into a properly arranged glass box we pass a fine wire through the sphere of oil, and by means of a handle cause it to revolve slowly, the sphere becomes an oblate spheroid; by increasing the motion we flatten it still more, until at a certain rate of revolution it becomes a disc, when a ring of oil is thrown off from the central globule, and although separated by intervening water, it revolves at precisely the same rate. It is not a little interesting thus to find mechanical science affording us the means of explaining the grander phenomena of creation.

The force of gravitation has its practical application in the ordinary forms of water-wheels, the falling water producing a continuous circular motion. In the hydraulic pressure engine, of which we have a beautiful model in the museum, the gravitating power of the water is the moving force. In the wind-mill we see the operation of the same power; and in the earlier engines, as those of Newcomen, Savery, and Watt's first single acting engine, the return of a heavy mass under the influence of gravitation and the atmospheric pressure—a result of the same principle—was the leading element of power. The works of Archimides and of Hero of Alexandria show us that the ancients were well acquainted with the operations of this agent, although they had not arrived at any correct idea of its law of action. It is to a neglect of the laws of gravitating force, and of the principle of action and reaction which prevails in every mode of motion, that the idle problem of producing perpetual motion has so frequently led ingenious minds aside from the path of usefulness which they would otherwise in all probability have pursued.

To continue our examination of the importance of minute observation, every step of progress from the employment of steam to produce a continuous motion, by Ptolomy Philadelphus, 130 years B. C., to the discovery by Watt of the expansive force of steam in 1782, might be quoted in exemplification.

We find Branca and Kircher employing the force of a jet of steam to drive the vanes of a wheel.

Baptista Porta observed the pressure exerted by confined steam, and he used it to raise water.

The discovery of the pressure of the air, and the investigations of Torricelli, Pascal, Guericke, and Boyle, led to the construction of engines by Worcester and Papin, in which the elastic force of steam and atmospheric pressure were combined in action.

Thomas Savery, carefully studying all that had been done previously, appears to have first conceived the correct *idea* of the force, and to have applied it with much greater success than any of his predecessors. In 1698 he got a patent for his discovery, calling it an invention "*for raising water, and occasioning motion to all sorts of millwork, by the impellent force of fire.*"

Newcomen, an ironmonger at Dartmouth, associated himself with Cawley, a plumber of the same place, and they together carefully investigated the phenomena of atmospheric pressure, and the formation of a vacuum by the agency of steam; and Newcomen certainly transformed an imperfect, and for many purposes a useless machine, into a really efficient steam engine, which could be applied profitably and safely to the most important uses. Newcomen should share a pedestal by the side of Watt; the ingenious contrivances of the obscure ironmonger of Dartmouth, the result of minute observation, have had much to do with the advance of civilization.

Of the inventions of Watt it is scarcely necessary to speak; the fertility of his genius is known to all; and the history of his progress informs us that every advance made by James Watt was a comment on the text I have chosen,—the value of observation. Of the importance of the inventions of James Watt well may Arago, in his *Eloge*, speak as follows:

“We have long been in the habit of talking of the age of Augustus and of the age of Louis XIV. Eminent individuals amongst us have likewise held that we might with propriety speak of the age of Voltaire, Rousseau, and Montesquieu. I do not hesitate to declare my conviction, that when the immense services already rendered by the steam-engine shall be added to all the marvels it holds out to promise, a grateful population will then familiarly talk of the ages of Papin and of Watt.”

Heat, as a force or principle, most intimately connects itself with the steam engine, and we are hence led on to a consideration of some of the phenomena which are associated with calorific action. Water at the level of the sea boils at 212° of Fahrenheit when under ordinary conditions. The minute observations of a Belgian engineer have led to the discovery that when water freed from air is exposed to heat, ebullition does not commence until it arrives at a much higher temperature, and that then it occurs with almost explosive violence. He has also proved that if water in this state is brought to the temperature of 250° or 260° , and then a single drop of water containing air be allowed to fall into it, that the whole volume becomes agitated in a terrific manner, that indeed an explosion occurs.

Who amongst the thousands inhabiting those regions of the earth, where water is rendered solid by the reduction of the winter temperature, but has noticed the air bubbles enclosed in the transparent ice? None of these thousands discovered a great fact in this until Professor Henry was led to examine it. The result of that investigation has been the discovery of the remarkable truth, that water in the process of congelation actually squeezes out everything it may hold in solution, and becomes far more pure than it can be rendered by any other means. If water holding air, colouring matter, or saline bodies in solution is, while being frozen, kept in a state of slight agitation, the air, the colour, and the salt are all rejected alike, and a tasteless, colourless, transparent ice remains. It is curious to see how near a great truth men often are, and how long they allow it to escape them. It has been the constant practice of the Russian nobles to place their wines in ice until they were frozen, for the purpose of obtaining the small quantity of ardent spirit left in the centre of the mass. The water of the wine in freezing liberated the alcohol and flavouring matter, and a pungent cordial was thus obtained.

Ice thus free of air, if melted out of contact with the atmosphere, may be heated to nearly 300° , when, instead of boiling, it explodes. How nicely balanced are the conditions of all things in nature. We now learn that if water was not the all absorbing body which it is, it would be as dangerous to expose it to heat as gunpowder or any other explosive compound. This interesting discovery promises to throw some light upon many of the steam-boiler explosions, which will form a subject of inquiry in the present course. As another illustration of the manner in which we have, from the defective character of our education, allowed phenomena continually presenting themselves to us to escape attention, look to the investigations of Boutigny. That drops of water thrown upon hot iron arrange themselves into spheroids, and move about with a peculiar internal motion, is nothing new. Yet who amongst us suspected that these dancing drops were telling a story to man which will in all probability completely change our ideas of the properties of heat?

If two similar metal vessels are taken, and one is filled with water, which is allowed by the action of an ordinary fire to boil in the common way, we know what then takes place; but if we allow the other to become red-hot before we fill it with water, and when full maintain it at a red heat, the water will never boil. The former vessel will soon be emptied by the evaporation of the water in ebullition, but that water in the red-hot vessel forming itself into a spheroid, rolls about, it never gains a higher temperature than 150° or 160° , and it evaporates but slowly. Again, at the temperature of red-hot iron chemical affinity is suspended, and if we project into an iron crucible thus heated, any bodies having the most powerful affinity for each other, they will not enter into combination, but remain separate spheroids rolling around each other. The investigations of Boutigny in this path have proved that the repulsive power of heat at elevated temperatures is so great that the naked hand may be plunged into melted iron without injury, and that the wondrous feats of the magians and the tricks of the conjuror can be performed with impunity by the philosopher. No less than three patents have been taken out in England for generating steam with great rapidity. In one water was dropped into red-hot tubes, in another it was thrown upon red-hot plates of iron, and in another heated mercury was employed. It was thought that the water would be *flashed* into steam, and an immense power obtained, but in every instance failure followed the experiment. The investigations of Boutigny show the cause of failure, and prove the importance of experiment at every step we make in our endeavours to employ the great powers of Nature to do us service. Recently in France attempts have been made to employ water in this spheroidal state to work a marine engine. It being thought that as the vapour which escapes from the spheroidal water is of the high temperature of the surface upon which it is formed, that it would, from its extreme tension, furnish an enormous amount of power. The experiment has not been, even in this case, successful hitherto.

Mr. Woolfe, to whom the Cornish steam engine is indebted for many improvements, once tried an experiment in the

presence of Mr. Davies Gilbert and some other gentlemen of a very remarkable kind, the result of which bears curiously on the investigations to which I have just alluded. A measured quantity of water was placed in a boiler, all the safety valves were most carefully closed, and every chance of the escape of steam prevented. The fire was now got up, and for some time the steam gauge indicated a regularly increasing pressure. At length, to the surprise of all, the pressure was seen slowly, but gradually, to diminish, and although the boiler plates became so hot as to char the wood which surrounded them, this remarkable phenomenon continued, and when the boiler had cooled it was found that no water had escaped. These investigators conceived no correct idea from this hazardous experiment, but it was the Caignard de la Tour experiment of enclosing elastic fluids in hermetically sealed tubes, repeated on a large scale, and it showed, as all the experiments of Boutigny show, that notwithstanding our boasted knowledge we are yet ignorant of the laws which govern the operations of heat when its excitation is elevated. The decomposition of water by heat, as discovered by Mr. Grove, belongs to this class of phenomena, and Dr. Robinson, of Armagh, in considering the experiment, speculates on the probability, that at a certain point *heat* may be changed into a *chemical force*, similar to those radiations from the sun which effect the changes now familiar to all of you in the photographic processes, to which the term *Actinism* has been generally applied.

Although it will be my constant endeavour to explain with all care the useful applications of science; to show how thoroughly associated science and practice should be, I shall never fail to direct attention to those experimental evidences which enable us to interpretate the great phenomena of nature. As a cultivator of physical science I feel that I should sacrifice half of the advantages to be derived from the study, if I failed to show the satisfactory manner in which advancing science opens out to the contemplative observer new harmonies in creation, and tends to exalt the mind to higher and holier aspirations.

In connexion with heat, observation has proved to us numerous important points relative to its distribution over the earth's

surface. The Isothermal bands connect themselves with the phenomena of animal and vegetable distribution; and still more strikingly we are beginning to discover an intimate connexion between those regions of mean equal animal temperature and the great phenomena of terrestrial magnetism. The conditions of the ocean currents,—as, for instance, the Gulf stream setting northward from the Gulf of Mexico, and ameliorating the conditions of our own winters,—are worthy of careful study. The waters of the sea upon our western shores are always several degrees warmer than the adjoining land, and during last winter the ocean temperature was found to be two degrees higher than usual. May not the mildness of that season have been due to the influence of that current of water, warmed in inter-tropical climes, flowing northward, and yielding up its store of heat to the shores of these islands?

This ameliorating influence is strikingly shown in Norway. On the southern coasts of that country, which are sheltered from the Gulf stream by our own islands, the cereals will not grow; but further northwards, where the great current setting to the north of Scotland reaches the Norwegian shore, the climate is rendered sufficiently mild for the growth of grain crops.

Again, the trade winds and the monsoons are entirely dependent upon the operations of heat; and careful observation has shown that the tornadoes of the West Indies and the cyclones of the Indian Seas are entirely due to the action of currents generated by the intensely heated surface of the earth. Notwithstanding the valuable researches of Sir William Reid, and others, proving the rotatory character of these storms, I am not satisfied that we have yet had a correct theory of the physical causes in action to produce them.

These storms are revolving masses of air, with currents rushing from the circumference to the centre, and blowing up through that centre; these systems of air in violent motion being sometimes many hundreds of miles in diameter.

The simplest explanation appears to be, that a comparatively small column of air is formed by contact with the heated earth, which ascends with much rapidity. Take the example of a jet

of steam, which in rushing from a boiler under high pressure draws all surrounding light bodies into it, and urges them upwards; the same phenomenon is shown in rapidly flowing water. The jet generates rapid currents on every side; these increase the diameter of the moving mass, and it progresses, continually increasing in size; all the currents rushing in towards a moving centre, and upwards through that centre as through an inverted funnel. The barometer is the truthful indicator of a diminishing pressure as the centre of the storm approaches the place of observation; and thus the mariner is, by careful attention to this instrument, enabled to determine the exact position in which his ship may be placed relative to that centre.

The importance of a knowledge of the Law of Storms, and consequently of the means of escaping from the influence of these hurricanes, and of indeed employing them to aid the ship's progress, cannot be overrated. The development of the Law furnishes a fine instance of the value of observation.

Examples of a similar kind might be quoted in connexion with electrical science. Careful observation has dispelled the erroneous idea of metals being lightning attractors; and we must be charged with negligence if we allow any elevated building to be without its pointed rod, by which the thunder cloud may be quietly discharged. The lightning is no more attracted by a pointed metal rod than is the rain falling upon a housetop attracted by the pipes placed so as to allow the water to flow to a lower level; the rods furnish the channel through which the electricity freely flows; and tower or ship may be surely protected if provided with bands or rods of copper sufficiently large to carry off the accumulated electricity, and to restore the equilibrium of forces.

The electricity of mineral veins has been a subject of much interest; it having been supposed that the currents detected were indications of the operations of this agency in producing the metalliferous deposit. From my own investigations in the principal mines in Cornwall I am disposed to consider these electrical currents as due to the chemical decomposition going on within the lode itself. It must, however, be admitted that the peculiar disposition of dissimilar ores within the same

mineral lode, the alteration in the character of the lode or vein after a dislocation has taken place, the generally uniform direction of lodes, and many other phenomena which it will fall to the province of my colleague, Mr. Warrington Smyth, to describe, appear to show the probability of such a power as electricity, in some of its modifications, being the exciting agent. This is one of those extensive subjects which yet remains open for the investigation of an intelligent and industrious observer.

In a course of lectures which is to embrace a consideration of the physical forces the phenomena of the solar radiations cannot be omitted. The practice of photography belongs to these, and furnishes another choice example of my text,—the value of observation. Omitting, however, all mention of the useful applications of photography as a means of making philosophical instruments self-registering, allow me to state that a careful investigation of the thermic influences of the solar spectrum, associated with a physical analysis of various transparent media, led me to the discovery of a glass, but slightly coloured green, which possesses the property of separating and keeping back a class of solar rays remarkable for their scorching power, and which, without obstructing any of the necessary radiations, thus protects the tropical plants in the great conservatory of the Royal Botanic Gardens of Kew from the injurious influences of scorching sunshine.

The solar spectrum exhibits several distinct phenomena. Light, heat, and chemical action are evident; and these give rise to electrical disturbance. Beyond these a class of radiations have been detected, which have the combined action of the heating and chemical rays, but which are in many respects dissimilar to either. These rays increase in quantity relatively to the other principle as the seasons advance; they being most abundant in the autumn; when, in all probability, they perform an important part in the ripening of fruit. These are the rays which, it has been found, operated to produce a kind of scorching on the leaves of those plants which grow in houses glazed with a white glass. To obviate this, was the problem submitted to my care; and the suns of two summers and autumns have shown that my experiments did not deceive me. No case of

scorching has taken place upon any of the plants in the beautiful palm-house in Kew Gardens. It is important to state that an entire absence of manganese in the manufacture of the glass is demanded, and that the addition of a small quantity of oxide of copper is required.

Did time permit me I might proceed to show you, that even those discoveries which have most the character of accidents, as that of iodine by a soap-boiler, and of the beautiful blue pigment, ultramarine, in the manufacture of soda; by generating ideas, which led to their scientific investigation, ceased to be so. Both iodine and artificial ultramarine form large branches of industry both having result from careful observation, and in the latter instance we have produced a pigment which formerly cost eight guineas an ounce now to be obtained for less than eight shillings a pound. Learn to observe closely and accurately, and numerous other similar results must be the reward.

Mechanical science embracing a consideration of all the means of employing the powers of Nature to aid man in subduing Nature, is necessarily a wide field. It will be my object in the first course of lectures on applied Physics to deal simply with the rudiments of our science, advancing gradually to the higher phenomena. To show the intimate connection of science and practice, the one aiding and advancing the other, will be my constant care, and in expounding the discoveries in Natural Science I hope to lead the mind to the study of those enobling truths which constitute a

“ Divine Philosophy!

Not harsh and crabbed as dull fools suppose,
But musical as is Apollo's lute,
And a perpetual feast of nectar'd sweets,
Where no crude surfeit reigns.”

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Government School of Mines and of Science applied
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WITH A VIEW TO THE
HEALTHY PROGRESS OF INDUSTRY.

(BEING AN INTRODUCTORY LECTURE TO THE COURSE OF
CHEMISTRY, SESSION 1851—1852.)

BY

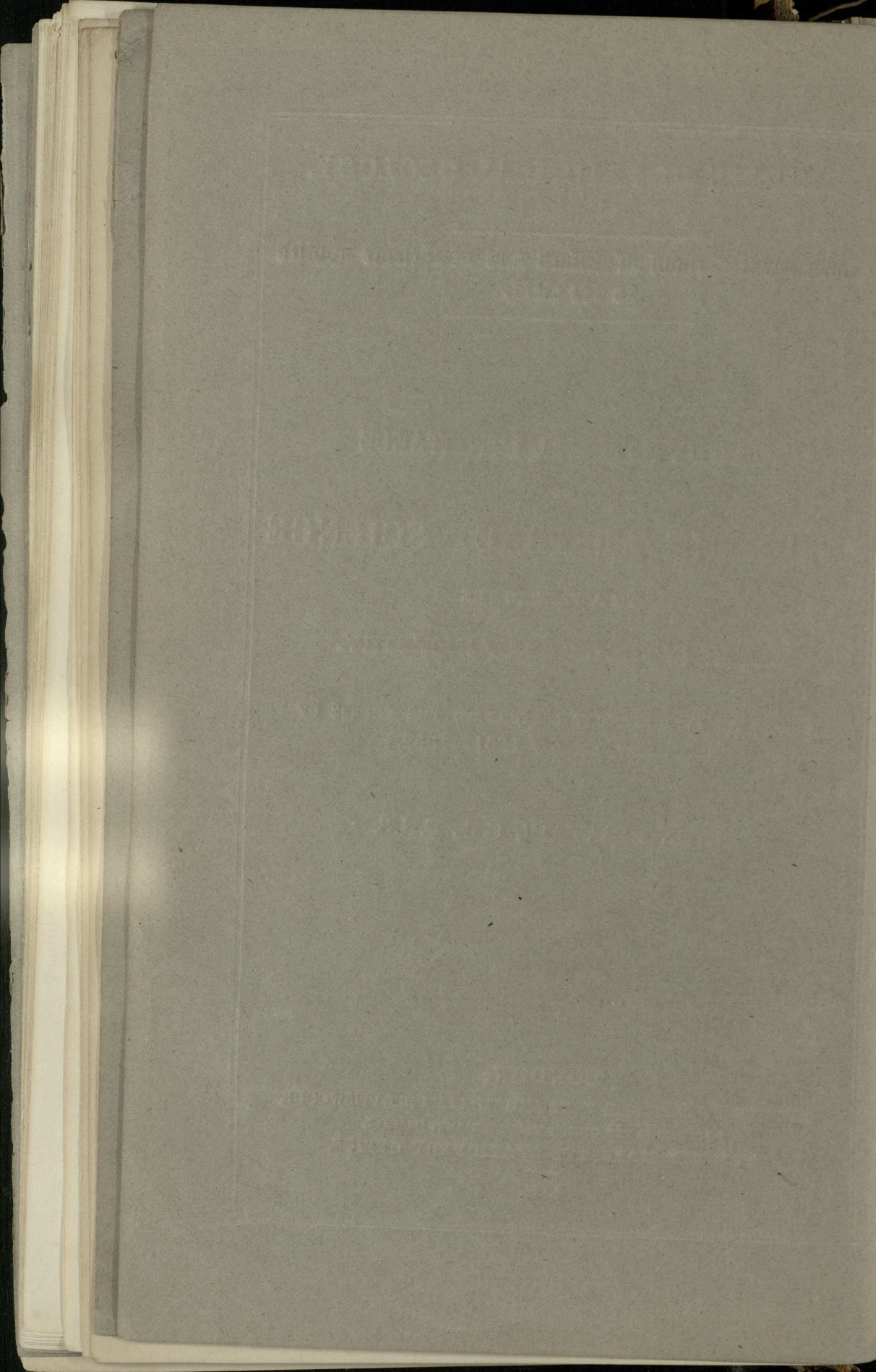
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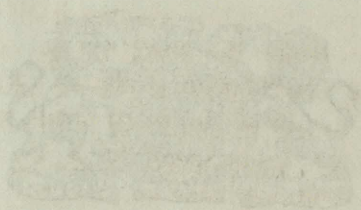
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1851.

THE raw material used by Industry for the production of useful objects doubtless forms the basis of manufactures, but possesses a fluctuating value in relation to that of the object into which it is converted. In the successful prosecution of manufactures, apart from the influence of mere capital and labour, two elements are involved, each forming a factor which in a competition of industry may be made to assume very different values. The first element is the raw material; the second, the skill and knowledge used in adapting it to the purposes for which it is designed. Thus, in America, cotton is indigenous, and consequently cheap; and fuel, the other raw material employed in its conversion to a textile fabric, is not expensive. In England, the same cotton is much dearer, but the fuel may be assumed to be equal in price. The competition between the two countries in respect to calico resolves itself into the necessity that England, to overcome the disadvantage of the greater cost of the raw material, must infuse a greater amount of skill and knowledge into the processes employed in its adaptation to useful purposes. England has succeeded in doing this; and, consequently, the mills of Manchester may render unproductive the

Note.—Some years since, I gave a lecture, never published, though a few copies were printed for private circulation among my students, the subject being similar to this. A demand having been made for it by publishers, as expressive of a want now acknowledged by manufacturers to exist, I have preferred taking this opportunity to write a new lecture on the same text, incorporating some of the passages of the former lecture.

mills of Lowell. But reverse the conditions of the two countries, and a similar result attests the truth of the same principle. Sheffield produces steel, which is exported in large quantity as a raw material to America. The history of that country has created a knowledge of the conditions required for the manufacture of edge-tools. The forests were not cleared, or the prairies converted into arable land, without that observing nation understanding the qualities and the requirements of the axe, the adze, and the spade. The knowledge thus attained was applied to the manufacture of edge-tools; and America returns to England its own steel, but under a new form, and endowed with an excellence, a temper, and a cheapness yet unattained by our artisans. Without this application of greater skill it would have been impossible for America to have competed with the country producing the raw material.

A nation, if it combine ordinary intelligence with its local advantages of cheap raw material, may long preserve almost a monopoly in special manufactures, and will continue to do so, either until the competing nation has risen so high above her in intelligence as to make this more than an equivalent for the local advantage of the other, or until a greater equalization in the price of the raw material renders a small amount of superiority in the intellectual element of sufficient importance to secure successful competition.

But should any great transition of the world take place, and should means arise by which local advantages were levelled, and the raw material confined to one country became readily attainable by all, the difference in its cost being inconsiderable, then the competition in industry must become a competition in intellect; and the nation most quickly promoting the intellectual development of its artisans must, by an inevitable law of nature, advance; whilst the country neglecting its industrial training must as inevitably recede.

It requires no mental acumen to perceive that we are rapidly approaching to, if we have not yet arrived at, this period of wonderful transition, when nations must speedily acquire the levels due to their different amounts of intellectual development.

It is quite true that a superabundance of capital may for a time preserve a country from a quick depression, even should it lapse in its intellectual training ; but the support thus given can only be temporary and illusory, for if, by the purchase of foreign talent, the necessary knowledge is infused into home manufactures, this can only have the effect of raising the intellectual element in the foreign country, and thus finally accelerate its success as a competing nation.

There never was a time when it was so necessary as now that skill and science should be united for the promotion of the industrial arts. At former periods of human history, local advantages or accidental combinations were the foundations of a nation's prosperity. The time is not distant when it was thought that the possession of mineral fuel indicated a country as the natural manufactory of the necessities of life employing machinery for their production ; while the existence of large tracts of land, warmed by a genial sun, stamped another nation as essentially agricultural, and employed its population in the labours of the field. Each country fell into a routine of manufacture ; and Italy and France produced their silks and shawls, with as little thought of competition as England its machinery and calicoes.

Science in advancing has created resources unthought of before, and has removed the local barriers opposed to the progress of industry. Countries were no longer confined in their aspirations by smallness of territory, for this by the aid of science enlarged its powers. The country able in its agricultural poverty to support only a scanty and miserable population, expanded itself for the reception of increased numbers as the produce of its land augmented, and thus knowledge, in the improvement of agriculture, won by a bloodless victory vast additional territory to aid in the industrial resources of the nation ; for a land, with a twofold increase in agricultural production, has, for all practical purposes, unfolded itself to twice its size. Science in its progress was improving and simplifying processes of manufacture, while it was opening at the same time a communication between the nations of the earth. The amazing facilities of transport afforded by the introduction of steam

enabled a ready interchange of their natural riches; and mere adventitious local advantages, apart from skill and science in their adaptation, became of much less moment than they formerly were. The proof of this is in the fact, that the staple manufactures are now carried on in all parts of Europe, and that there is a constantly increasing and active competition of most of the great nations in all the markets of the world. If England still continue in advance, it will not be from the abundance of her coal and iron, but because, uniting science with practice, she enables her discoveries in philosophy to keep pace with her aptitude in applying them.

But is it true that England does act thus wisely; and is it true that science does hold in this country its just position in public esteem, or that it is fostered sufficiently to make that progress which it is now doing in other lands? To all such questions a negative reply must be given; for beyond a theoretical recognition of the importance of science in its relations to practice, and the establishment of this museum and college—a very important measure, I admit—the state and the public only look to the empirical result, and have not deemed it necessary to foster the knowledge producing it. But England is the only European state thus blind to its own interests, and not yet thoroughly awakened to the importance of giving an intellectual training to those intrusted with its manufactures. This is proved by the large endowments given by foreign governments for the support of institutions connected with industrial science, and it finds expression in the writings of their thinking men. “An equal appreciation of all parts of knowledge,” says Humboldt, “is an especial requirement of the present epoch, in which the material wealth and the increasing prosperity of nations are in a great measure based on a more enlightened employment of natural products and forces. The most superficial glance at the present condition of European states shows, that those which linger in the race cannot hope to escape the partial diminution and perhaps the final annihilation of their resources. It is with nations as with nature, which, according to a happy expression of Goethe, knows no pause in ever-increasing movement, development, and production—a curse still cleaving to standing still.”

“Nothing but serious occupation with chemistry and natural and physical science can defend a state from the consequences of competition. Man can produce no effect upon nature, or appropriate her powers, unless he is conversant with her laws, and with their relations to material objects according to measure and numbers. And in this lies the power of popular intelligence, which rises or falls as it encourages or neglects this study. Science and information are the joy and justification of mankind. They form the springs of a nation's wealth, being often indeed substitutes for those material riches which nature has in many cases distributed with so partial a hand. Those nations which remain behind in manufacturing activity, by neglecting the practical applications of the mechanical arts and of industrial chemistry, to the transmission, growth, or manufacture of raw materials—those nations among whom respect for such activity does not pervade all classes—must inevitably fall from any prosperity they may have attained; and this by so much the more certainly and speedily as neighbouring states, instinct with the power of youthful renovation, in which science and the arts of industry co-operate or lend each other mutual assistance, are seen pressing forward in the race.”

It is but the overflowings of science that thus enter into and animate industry. In its study we are never sure that the morrow may not gladden the world with an application of a principle to-day abstract, and apparently remote from practice. This is a truth above all things necessary to convert into a living faith in the minds of those who devote their lives to its practical applications. Nothing is more erroneous in their case than to neglect the acquisition of abstract scientific truths because they appear remote from practice. I do not admit that it is even wise to address to oneself the question *cui bono*? Science is too lofty for measurement by the yard of utility;—too inestimable for expression by a money standard. These groveling ideas of the objects of science, which constantly jar it in its intercourse with the world, ought to find no response in the breast of any devotee who would draw inspiration from its shrine. But whilst I protest against the indulgence of a mere utilitarian appetite for science, I think it infinitely advan-

tageous to examine it in its practical relations to life ; but it must not be forgotten, that though the object of industrial study is to view science in its beneficent overflowings of kindness to man, these material benefits arise from the very fullness of its measure. If we revert back to the intellectual wanderings of science in its search for truth, it becomes surprising how soon it shook off the trammels of ignorance, and developed into a glorious liberty. Let us recollect how much science has advanced within the last three centuries, and even her past history becomes more remarkable in its progress than the present. It is no mean task for intellect to leap over the barriers of ignorance ; it is even more easy to go onward in new and untrodden paths. It was only at the end of the sixteenth century that the Council of Sages at Salamanca negatived the idea of a western continent, by the writings of Lactantius. "Is there any one so foolish," says he, "as to believe that there are antipodes with their feet opposite to ours ; people who walk with their heels upwards and their heads hanging down ? That there is a part of the world in which all things are topsy-turvy ; where the trees grow with their branches downwards, and where it rains, hails, and snows upwards ?" Do we not know that Columbus was told by the Sages, that were he to succeed in sailing down the rotundity of the earth its bulging out would prevent him ever sailing up again ; and do we not remember with what a stedfast faith in abstract truth he saw beyond "the region of the torrid zone, scorched by a blazing sun, a region of fire, where the very waves which beat upon the shores boiled under the intolerable fervour of the heavens ?" Recollect that these were the opinions of a time when the utmost national encouragement was given to intellectual progress, and that it was not very many years after the death of Prince Henry of Portugal, who gave that glorious motto to princes, "the talent to do good." Recollect that this ignorance was manifested in the brightest time of the reign of the enlightened Isabella of Castile, and you will be surprised with me that science has since that time achieved what it has. Had Columbus not investigated the abstract truths of cosmography, the western continent, even with the advantage of the "astrolabe," discovered in his time, would perhaps for a century have re-

mained unknown. It is easy to make an egg stand on its end when the way is shown how to do it. The applications of science are not difficult, but without the science there are no applications. The philosophy of our times does not expend itself in furious discussions on mere scholastic trivialities, or unmeaning questions in theology. The scholastic learning of the middle ages was much confined to ecclesiastics, and it is not surprising to find both classical and theological literature engrafting itself upon the science of the time, and forcing it into the discussion of questions very foreign to its nature. It was a curious mixture of theology and science when the most learned men agitated themselves on subjects such as—the manner in which angels are nourished?—whether they usually speak Hebrew or Greek?—what are the spirits entrusted with the distribution of lightning and hail, and to which are confided the digestive powers of animals?—whether Adam, before the Fall, was acquainted with the *Liber Sententiarum* of Petrus Lombardus? The polemics of a past age do not represent the search after abstract truth of the present. Yet you are in no position even now to treat with derision the past errors of philosophy. The man who is on the mountain complains of the fog obstructing his view, while the inhabitant of the plain speaks of it as a cloud capping the mountain. Both are right, but read the phenomenon differently from each other. Yet only he that was in the fog could rightly appreciate its darkness, or fully understand the force of the rising sun that dissipated its obscurity. The progress of knowledge,—the search after truth,—can scarcely be recognized in its sublimity by those who do not understand the errors which had to be swept away before it could advance in an uninterrupted path.

There are very few instances in the history of science of a sudden development of great discoveries, either illumined from darkness by a flood of light from genius, or betrayed through some accidental and straggling ray. The growth of scientific discovery is slow, and does not, like the prophet's gourd, spring into full development in a single night. The great discoveries of science leave behind them no boundary line of demarcation from those which have preceded, but, like the full day succeeding

the dawning of the sun, follow that which fully foretold their approach. The telescope and microscope did not open their wonders to an unexpected and startled world, but crept into existence with steps so slow that their impression is not sufficient to trace out the history of their progress. The improvements in the steam-engine were so gradual that a court of law, only half a century since, gave a solemn judgment that Watt had done nothing essential towards them. The compass cannot point to us the period when it offered its inestimable services to man, nor has paper left a record of its discoverer. In fact, all great practical discoveries are the result of much study, the exponent of a long series of observations, and often arise out of those truths of science which appeared least promising on their first announcement. Boyle knew that he wrote an imperishable truth when he titled his Essay "Man's great ignorance of the uses of Natural Things; or, that there is no one thing in Nature whereof the uses to Human Life are yet thoroughly understood." This truth of the seventeenth century is no less true in the nineteenth, the history of the intermediate time having been, as Sir John Herschel justly remarks, but one commentary on the text. The everyday progress of the arts abounds in new applications of objects the most familiar.

Practical, like abstract science, has no limits. The Romans thought themselves at the culminating point of civilization; and the Greeks, pluming themselves in their inventiveness, could not conceive that the world would ever take a higher flight. Even in our times, like opinions are entertained; because ignorance cannot see over the heights raised by modern science for a wider view of creation. These conceited ideas of a nation or of an age have no foundation. Science may see an horizon bounding her view; but as she proceeds onward the horizon constantly recedes, and shows the limit to be altogether illusory. In one time and generation a nation may, like Newton, pick up a few pebbles on the seashore, while the boundless ocean of science lies beyond, with all its vast and unexplored treasures.

Empiricism has frequently been a substitute for science; a lame and sluggish substitute, it is true, but nevertheless one

that in the history of mind has had much of influence. Gunpowder was known before the condensed air of which it consists was recognised or understood; and it succeeded in killing man, without a knowledge that man himself is little more than air similarly condensed. Man used and succeeded in producing condensed air in the form of food, without having the slightest conception of the character of the air out of which this wondrous transformation was effected. Without a knowledge of atmospheric pressure, mills and pumps were formed. Glass was produced from the ashes of the fern, and china from kaolin, without a knowledge of the principles involved in their production. The length of the year was known, and the duration of the seasons explained, without the law of gravitation being suspected. All this, it is true, arose without science, but required ages to grow into a stunted and feeble childhood; while no sooner did science remove the trammels of ignorance, than a few short years produced a vigorous manhood. Ignorance may grope in darkness on the confines of an unexplored region, but to proceed steadily and securely onwards she must borrow the lamp of science to guide her. Newton, "that glory to his species," as Chalmers calls him, did, by the exposition of the law of gravitation, produce more real practical benefits to industry than all the preceding ages of empiricism. Navigation and Commerce sprang from his time into a state of development formerly impossible; and every nation and every human being enjoys from him, and to the end of time will enjoy, actual material benefits which an eternity of empiricism could not have produced. The hard-won experience of two thousand years of the Chinese in regard to porcelain was given to the European by a few years applications of science. The improvements in postal communication, which allowed our kings to transmit a message to Edinburgh in five days, now enable us to send it in less time than their "post-haste messenger" could saddle his horse. But these, and other triumphs of mind over mere empirical experience, arose from a steady progress of abstract science, the practical applications appearing merely as offshoots. It is my chief object to show that abstract science is necessary to the development of

practice, and that it is above all things necessary to make it a part of the education of a man who is to devote his life to the progress of industry. There is no vein of science too abstract for future industrial application ; none yet thoroughly mined out and exhausted. Volumes might be filled with illustrations of the practical benefits produced by the application of discoveries apparently the most unpromising in their origin ; but a few only can be selected in support of the text of my argument.

The most "practical" man,—a title erroneously used by our English to envelope their ignorance,—could not have objected to the marvellous development of truth arising from the study of light, that messenger from the sun travelling to us at the rate of 180,000 miles in a second, to illumine our earth with the glory of its parent. It was wondrous to be told that the light of yonder far-distant fixed star, travelling without cessation at the same incredible speed, and which has this night struck our wondering eyes, started in its long and weary course some billions of years since, and has now for the first time shed its pale light on such points in time and space as ourselves. The sublimity of these truths awes the utilitarian, and hushes his half-uttered question of *cui bono*? But show him a young officer of artillery looking through a prism at the windows of the palace of the Luxembourg, and noticing that, in a particular position, the light of these windows disappeared from his view—show him, further, the startled wonder with which the philosophers of Europe heard of this phenomenon, and the eagerness with which they threw themselves into the track of an observation apparently so insignificant,—and your utilitarian sneers at science and its followers, and buries himself again in the darkness of his empiricism. The light reflected from the palace of the Luxembourg had suffered a change similar to that experienced by ordinary light in passing through doubly refracting Iceland spar. When a ray of this changed or *polarized* light is passed through plates of crystallized substances, brilliant colours and a peculiar structure are observed. These remarkable phenomena were indeed well worthy of the attention of scientific observers. Nothing, however, could

appear more remote from practice than the study of an altered beam of light. It was most interesting that, as in the case of sound, where two sounds reaching the ear either exalt or destroy the effect, so, in light, two rays interfering with each other may produce darkness. Much of the light from reflecting surfaces was found to possess this changed condition. The light coming from the surface of water being thus altered, refuses to pass through a "Nicolls' prism" in a particular direction. If, therefore, you look at the shadow of a man on a smooth lake, on turning round the prism the shadow disappears, while the man, seen by common light, remains visible. The story of Peter Schlimmel is thus realised. But who, from these curious observations, would have dreamt that out of them would come useful applications?

In a short time, however, this property of the polarizing prism was applied to the important purpose of detecting rocks and shoals at sea. It had long been the practice of mariners, when they suspected the existence of shoals, to look out for them at the masthead, because the outlook from his vertical position shut out much of the light that dazzled and obstructed his view. But as part of this dazzling reflected light is polarized, it is obvious that the polarizing prism enables the observer to scan the depths of the ocean, uninterrupted by its glare. Behold then the light which struck the student's eye when gazing on the Luxembourg used to preserve man from the hazards of the sea. It was easy to apply it in new directions; and the salmon-fisher speared fish at depths inaccessible to his unaided vision; while the engineer used its searching powers to discover the laws of tension in beams. Mechanics and chemistry both pressed it to further their resources. Under the hands of a Biot, a ray of polarized light performed with magical quickness the most refined but tedious operations of the analytical chemist, and enabled him to tell the amount of sugar in the cane or beet juice. He thus followed the increasing richness of sugar in the juices of various plants at different stages of their growth, and was enabled to suggest a more economical adaptation of the labour applied to their cultivation. Thus, when beet is ready to be gathered, labour is in demand for the harvesting of other

crops, and consequently is expensive. It would not then do to take another crop, such as parsnips, inferior in its amount of sugar, as the cost of production would outweigh the return; but when the horses and carts are disengaged, and labour is cheap, parsnips are richest in their amount of sugar, and the idle mills may be usefully employed in producing sugar from this plant. By the same ray of light the size of distant objects may be measured, and even time may record its passage. This latter application, made by Wheatstone, is especially remarkable, and gives a means more accurate and useful than the sun-dial of determining the apparent solar time by the diurnal changes of the plane of polarization at the north pole of the sky. By availing himself of the fact, that the planes of polarization in the north pole of the sky change exactly as the position of the hour circle alters, he has adapted a simple and ingenious apparatus, by which the true time may be told within three minutes. All these are strange paths to practice, opened out by a ray accidentally caught in its passage from a window of the Luxembourg. Pass from its utilitarianism to its unfolding of nature's laws, and follow the same straggling ray, as it silently displays its gorgeous colours while passing through a transparent mineral substance, until it gives to man the knowledge as to whether the light of the sun proceeds from its solid mass or from its gaseous canopy, or whether comets enjoy light of their own, or borrow it by reflection from other bodies.

I now pass to light in its ordinary form, and ask you to examine the importance of studying its abstract phenomena. The world had long known that salts of silver were blackened by exposure to light; and the fact became familiar by their use as cauteries, or as indelible inks for linen, Wedgwood proposed to apply this means to fix the fleeting pictures of the camera obscura; but the results of his experiments being imperfect, the suggestion itself was almost forgotten. In the meantime chemists pursued their abstract discoveries, and without relation to this want investigated the properties of gallic acid, and of the iodide of bromine, and found a class of salts termed the hyposulphites. Some of these bodies pos-

sessed properties accelerating the blackening of silver salts by light; the others prevent the further blackening when applied. Philosophers began now to revert to the old idea, for truth is never lost, though its reality may be incapable of proof at a given time; and thus various unconnected discoveries began to react one upon the other, until man was able to use the sun as the painter of the pictures exhibited and enlivened by her glory. So perfect became the art, by new adaptations of other discoveries, that the most fleeting objects can be depicted. The flash of lightning exhibits its fiery streak on these sun-painted pictures. The tossing out of lavas, the vomiting forth of smoke, and the bellowing of flame from craters in their wildest moods, are pourtrayed with unerring fidelity; the tumultuous dashing of the cataract and the slight rippling of the stream, the changing forms of the clouds, the sparkling of the rain-drop, and the ever-varying expression of the human countenance, are all capable of being preserved in these paintings by nature. Nay the truthfulness of the sun-painted landscape is so great that from the very shadows of the picture the altitude of the sun may be determined; and the time at which it was taken being known, the latitude of the locality may be elicited. Artists now use this application of light to acquire models for study; and the engineer employs it to obtain proofs of the exact state and progress of the works superintended by him. Doubtless very soon, for it is now all but accomplished, the sun will be compelled to fix those transitory coloured glories which she now imparts to natural objects; but not till then should man cease to question her as to the means of accomplishing this end. I need not say that this art is but disclosing its future applications. Already can we use the sun to record observations too delicate for man's perception. The constant and momentary excursions of the magnet, the ever-recurring variations of the thermometer and barometer, are now recorded by light with a fidelity and precision unattainable by the most conscientious and unremitting observers.

These instances will suffice to show that the study of abstract laws, so far as regards light, produces as offshoots important practical applications; and in each department of science, like

lessons may be taught. There never was an age so rich in practical applications as that in which we live, and it is interesting to see them drawn from truths long familiar to man, and apparently beyond the range of utilitarian application. When an Italian physician, having hung on an iron railing the legs of a frog fastened to copper hooks, observed that each gust of wind caused convulsions in the legs of the dead animal, who could have prophesied that this accidental observation would entirely alter the character of a future century; and yet it is but an application of this discovery, extended, it is true, by many intermediate researches, that annihilates space and time,—that empowers our thought to travel with the speed and with the power of lightning to the most distant land, and enables mind to be reciprocated without being arrested by distance in space. Who could have dreamt that the same discovery of Galvani would in future join continents, in spite of intervening seas, and give more security to nations than cordons of soldiers or fleets at sea, by rendering sudden invasion all but impossible. At the late Exhibition you had a singular proof of this quick interchange of intelligence, for every morning you could buy at a trifling cost a map showing the state of the wind, of the barometer and thermometer, in all the principal towns in Great Britain during the previous day. You have already seen how useful may be made this discovery; for a transit of a star at Greenwich and at Paris may be instantaneously recorded, and their respective longitudes verified. As a means of communicating intelligence, its powers are not yet nearly developed; for in its mercantile communications it produces results no less individually important than in its general results, such as when it sends information to distant provinces of the approach of a tornado, time being thus given to provide against the fury of the storm. It is rare indeed that brilliant discoveries, such as the electric telegraph, flash matured across a human intellect, and in a generation produce such mighty results. It is true that some of the most wonderful discoveries have been shadowed forth by a sudden inspiration; but in few cases has that shadow appeared as a picture with all its lights and shades. Before steam had been subjugated to the service

of man, in accelerating his transit on land or water, Darwin had said,

“ Soon shall thine arm, unconquered steam, afar
Drag the slow barge, or move the rapid car.”

It was a similar inspiration that showed to Goethe that the parts of flowers are metamorphosed leaves, and that made Oken, when stumbling over a bleached skull, perceive that the osseous system was constructed on the vertebral type. But it was only by patient and long-continued study that these thoughts became substantive realities. This is essentially the case in electricity, which is but now beginning to reward mankind at large for all the patient investigations of the philosopher. Already has the fierce and untamed lightning allowed itself to be dragged from its course, and be conducted tranquilly to places where its fury is dissipated without injury to man. Even in its fiery flashings in the wide expanse of the ocean, it submits to the intellect of a Franklin, and leaves unscathed the ship rolling on the stormy waves. Providence, in His beneficence to man, has allowed him to find “ a way for the lightning of thunder.” Artificially formed, it allows itself to be conducted through land and sea, humbly serving the purposes of man, by blowing up mines, or enabling him to rescue treasures from sunken vessels.

This immaterial power produces material results at places fixed on by the will of man; and London may now fire a friendly salute at the Invalides, while Paris returns the compliment with the guns of the Tower. Although, as yet, electricity is not used with economy as a motive power, the obstacle is only in the cost; and even this may be resolved as discoveries progress.

Although her passage is so rapid that a journey to Paris can scarcely be expressed in time, yet she may be controlled, and used to record time's own progress; for nothing is more accurate than clocks worked by her power. It would not be difficult to have all the clocks in a town worked with perfect uniformity by the aid of electricity.

Electricity now plates with gold and silver the baser metals; copies in metal from more perishable materials the most exquisite designs and forms; perpetuates the skill of the engraver, by

multiplying, at a trifling cost, his elaborately engraved plates ; and separates and purifies the metals, formerly only obtainable by tedious and complex chemical operations.

Electricity offers for your lighthouses light of a brilliancy the most intense, and asks you to substitute the light gas which streams through the streets by a still more ethereal existence, running along simple wires.

Even in the smallest offices of good-will to man she refuses not her aid, and offers to tell the perfumer whether his essential oils are adulterated with cheaper fatty substances, as willingly as she lends aid to the chemist in the minute operations of his laboratory practice, or as she kindly ministers with the physician to allay human suffering and restore wasted strength. Recollect, that all these are but the beginning of her applications, and that we know not to what extent they may be carried out ; and rejoice with me that philosophers studied her abstract laws, from the knowledge of which these applications have arisen.

I have no time to extract further examples from physics or meteorology, but I cannot refrain from directing a passing glance at the beautiful discoveries of Colonel Sir William Reid. Studying the phenomena of a hurricane at Barbadoes, he followed out his observations to all recorded hurricanes, and thus elicited the simple law that hurricanes and many gales are progressive whirlwinds, revolving in the direction of the hands of a watch in the southern, and in the reverse direction in the northern hemisphere, but moving along in its mass at the same time. The variable winds in a hurricane now become intelligible, and a mariner caught by it may use every wind to steer out of its course, and prevent himself being overwhelmed in its vortex. To be wrecked in a hurricane, with an open sea, can now only result from a lamentable ignorance of scientific laws ; for knowledge has triumphed over the terrors of the storm.

Let us now turn to chemistry proper, and see how this supports the text of the argument. It is an old science, and from the time of Tubal Cain to that of Liebig has been progressing steadily onwards, though not always with similar aims and aspirations. The alchemists erred, as England now errs, by valuing and studying only practical applications, instead of following

abstract laws. Health, wealth, and longevity comprised their aspirations, in the place of eternal truth. But these objects were sufficiently important to produce in their search "a zeal allied to madness," and facts became accumulated of infinite importance to the science when it attained self-consciousness, and learned to value itself for its nobler ends.

No later than the time of Henry IV., a royal edict recommended that "the clergy should search for the philosopher's stone, for since they can change bread and wine into the body and blood of Christ, they must also, by the help of God, succeed in transmuting the baser metals into gold."

As soon as chemistry began to be studied for the mere sake of abstract truth, then she deigned to reward man for his unselfishness by numerous collateral results having a direct material benefit.

"The philosopher's stone," says Liebig, "for which the ancients sought with a dim and ill-defined impulse, was, in its perfection, nothing else than the science of chemistry. Is not that the philosopher's stone which promises to increase the fertility of our fields, and to ensure the prosperity of additional millions of mankind? Does not chemistry promise, that instead of seven grains we shall be able to raise eight or more on the same soil? Is that science not the philosopher's stone which changes the ingredients of the crust of the earth into useful products, to be further transformed by commerce into gold? Is that knowledge not the philosopher's stone which promises to disclose to us the laws of life, and which must finally yield to us the means of curing diseases and of prolonging life?"

He who supposes that chemistry is the result of practical knowledge derived in its contact with industry knows little of the progress of the human mind, or is little grateful for the infinite development which it has given to human resources and human enjoyment. Let us select a few examples of abstract chemical truths bearing on practical appliances. I will first refer to the Miners Safety Lamp as a most important example of an industrial result depending upon pure induction from abstract science. An element of destruction, apparently uncontrollable by human power, had to be subjugated so completely as to be put under the management of the most uneducated

miner. More dreadful in its effects than those of the lightning and the earthquake, fire damp, the scourge of the miner, seemed to defy investigation even as a scientific phenomenon. By a pure inductive method, such as a Bacon would have loved to witness, Davy traced its history, step by step, until he fully made out all its characters. He discovered that it in reality requires a very high heat for ignition, the temperature of red-hot iron or charcoal being insufficient to inflame it. The gas was found not to explode in narrow tubes, as these cool it below the point of ignition; and a network of iron wire is only a series of sectional tubes. A lamp surrounded by wire gauze is now constructed, and this allows a light to be carried into the most dangerous mine with perfect safety. What a wonderful discovery is this! The destructive gnome of the mine is imprisoned within a cage of mere wire gauze, and, vainly struggling to escape, heats to redness the bars of its prison. Science, to its glory, has destroyed those scenes of death and heart-sickening misery which haunted the miner in his most peaceful hours, and has rendered safe an occupation formerly one of dread and danger.

When Dumas investigated the laws of substitution, and discovered a new body by distilling alcohol with bleaching powder, interesting indeed in its chemical formula, but capable of being sneered at by those who see science at a distance, by a wrong-end telescopic view of its commercial productiveness; who could have dreamt that this *chloroform* was destined to remove many of the woes which man is heir to, by mitigating pain, and preventing its occurrence even in the most severe surgical operations?

In 1842, I had the pleasure of travelling with the Dean of Westminster and Liebig over different parts of England. Among other places we visited a limestone in the neighbourhood of Clifton, where in former times saurian reptiles had been the pirates of the sea. There, along with the relics of the fishes on which they had preyed, were their own animal remains. Coprolites existed in great abundance, and proved the extraordinary number of the reptiles which must have existed. The interesting question arose as to whether these excretions of extinct animals contained the mineral ingredients of so much value in

animal manure. The question was in fact not yet solved by the chemist, and we took specimens, in order to confirm by chemical analysis the views of the geologist. After Liebig had completed their analysis, he saw that they might be made applicable to practical purposes. "What a curious and interesting subject for contemplation! In the remains of an extinct *animal* world England is to find the means of increasing her wealth in agricultural produce, as she has already found the great support of her manufacturing industry in fossil fuel—the preserved matter of primeval forests—the remains of a vegetable world! May this expectation be realised! and may her excellent population be thus redeemed from poverty and misery!" I well recollect the storm of ridicule raised by these expressions of the German philosopher, and yet truth has triumphed over scepticism, and thousands of tons of these or similar animal remains are now used in promoting the fertility of our fields. The geological observer, in his search after evidences of ancient life, aided by the chemist, excavated extinct remains which produced new life to future generations.

Two years before this, the same German philosopher, in his researches into the food of plants, had drawn attention to the importance of guano as a manure, and by his intellect wafted fleets to the Ichaboes and to the Incas.

Man gets so accustomed to luxurious applications of science, that he often forgets the searcher of abstract truth whose discoveries led to them. Nothing is more useful than has been the discovery of the lucifer match. Some of us recollect the time when the tinder-box was the only artificial means of procuring light, and a lively remembrance of the often-unsuccessful efforts, always tedious and lengthy, is required fully to appreciate the value of the lucifer match. What an improvement it was when a little bottle of oil of vitriol could be carried about, and by dipping matches into this, light was obtained! And yet this elegant method is now considered clumsy, and is entirely superseded in less than ten years. The properties of chlorate of potash and of phosphorus became by study better understood, and their application to the production of artificial light was apparently perfected. But the lucifer

match maker is dangerous to society, and a curse to himself. The transparent waxy phosphorus with which he works must always be kept under water, and even then is so hazardous that insurance offices decline to insure the premises in which it is contained. The heat of the hand causes it to inflame, and the worker, even avoiding this, becomes diseased and liable to ulcers. The practical man now helplessly lays his wants before the searcher of abstract truth. Chemists had for some time noticed that various bodies assume different forms, as, for example, carbon, in the states of diamond, graphite, and charcoal. An Austrian chemist, Professor Schrötter, investigating the abstract laws of allatropism, inquires whether phosphorus has more than one form, and by heat changes the transparent wax into a scarlet body. This scarlet substance is the same phosphorus, but in a state in which it may be kept in the open air, or packed up and transported in casks, and is not readily inflamed by a gentle heat or by friction. Physiologically it has little action on the body, and yet by proper admixtures makes as good lucifer matches as the ordinary dangerous phosphorus. By these discoveries the means of giving artificial light is rendered a safe and healthy manufacture.

A French chemist discovers that paper immersed in nitric acid unites with that body, and becomes highly combustible. Any woody fibre is subsequently found to do the same. This observation lies dormant for years, noticed only as an interesting fact, under a long and scientific term, in the books of chemists. But one day a Swiss chemist announces the startling fact, that the peaceful cotton bales of Manchester may be converted into dangerous ammunition of war, and that cotton unchanged in its physical appearance has been made more destructive than gunpowder. There was something appalling in the fact of this peaceful representative of industry being made to assume such destructive properties, under the magic wand of the chemist. The chemist now examines cotton in the new form, and trying to purify it, finds that it is soluble in ether. When left exposed, the ether quickly evaporates, and the gun-cotton retains a skin-like appearance. Surgeons seize the discovery of the chemist, and gun-cotton dissolved can heal the wounds it makes in its dry

state. Numerous applications follow, and man, forgetting his fear, uses the gun-cotton to silver mirrors, and to produce the portraits of his friends on glass, by a process speedy as the Daguerreotype. Another chemist, seeing how readily cotton unites with acids, investigates its power of combining with alkalies. He discovers that it does so, but notices that a contraction ensues in its fibres. Looms are not now required to make coarse calico fine, for immersion in soda makes it take the form of fine cambric. The alkaline calico washed in water loses its soda, but unites with water, and this in turn is displaced by colours when the calico is dyed, so that the calico assumes dyes of much greater intensity and brilliancy.

Analogous to this is the application of a well-known fact to the manufacture of flax cotton. As long ago as the time of Solomon, it was well known that acids produce an effervescence with carbonate of soda, for that wise King says, singing songs to a heavy heart is like pouring vinegar upon natron (mis-translated nitre). This old fact is now used to separate the fibres of flax, and give to it a cotton-looking appearance and properties. But this would have been insufficient as a practical result, had it not been that scientific discoveries had shown the existence of a class of bleaching compounds, termed hypochlorites, which enable a few hours to do the work of many weeks. These various facts, one acting upon the other, have led Chevalier Claussen to his interesting process.

These various discoveries of Schonbein, Mercer, and others, did not in any case arise from a direct practical search, but as offshoots of abstract investigation.

Antioch, in the beginning of the fourth century, discovered the importance, as a matter of police, of lighting its streets. But the discovery lapsed, and it was only in the middle of the sixteenth century that Paris lighted up her streets by fires made of pitch and rosin. Slowly did this matter of primary police creep on till the end of the last century, when it started forward with extraordinary vigour. Chemists had long observed that coal on being distilled produced a combustible gas, and the means of collecting and distributing various kinds of gas were among the common experiments of a lecture table. But it was not till

1792 that Murdoch employed coal gas to light up his offices at Redruth. Now gas has entirely substituted oil in the lighting of streets, but simply as a question of cost, the coals from which it is produced being cheaper than the corn necessary to form tallow. It by no means follows that gas is always the most convenient form of using a combustible. "It would certainly," says Liebig, "be considered one of the greatest discoveries of the age if any one could succeed in condensing coal gas into a white, dry, solid, odourless substance, portable, and capable of being placed upon a candlestick or burned in a lamp." A want is rarely clearly expressed by man that science does not administer to it; and already is the desire of Liebig accomplished. A mineral oil flowed out of coal in Derbyshire, and was obviously produced by a slow process of distillation from the coal. It contained solid paraffine dissolved in a liquid oil. Mr. Young, of Manchester, in examining the mode of its formation, found that paraffine, a solid waxy substance hitherto never produced from coal, could in reality be readily formed in commercial quantities by a slow and regular distillation. This, in fact, is "condensed coal gas," or, rather, it might be considered as a solid form of olifant gas. It is therefore really the want of Liebig supplied. In forming coke, this product, dissolved in an oil of a similar composition, may readily be obtained; and useful products are made instead of those waste gases now thrown uselessly into the atmosphere. It might appear chimerical to you if I were to state many of the consequences which must follow if this discovery in its maturity be found as successful as it promises to be in its dawn; but it is not difficult to see that a cheaper and less carbonised coke could be burned in our domestic fires; and thus we might see a sun which now refuses to penetrate the sooty canopy of our cities.

Hour after hour might be employed in recording the triumphs of chemistry in its investigations into the play of the organic elements. Looking back no further than the last few years, you see how it has thrown open the most hidden processes of animal and vegetable life; how it has taught us to increase and economise the food of man. It is even yet the practice of those who have not followed her discoveries into the wondrous affini-

ties of the few simple organic elements to depreciate the importance of following their infinite creations. If, however, there were no other result from doing so than the one great achievement of having explained the ingredients in food used to build up the muscular frame and those employed in the support of animal heat, the importance of that discovery would have repaid all the labour of the past century.

Almost all the staple manufactures of this country are founded on chemical principles, a knowledge of which is absolutely indispensable for their economical application. In a few educational establishments and in some of our universities the alphabet of chemical science is taught; but it requires an institution such as this, devoted to a special object, to teach how to use that alphabet in reading manufactures. The extension of scientific and technical education is a want of the age. The old and yet widely-existing scholastic system of education introduced by the revival of learning in the fourteenth and fifteenth centuries is ill adapted to the necessities of the times. Erasmus would not now aid Cambridge in advancing the progress of England, nor would Vitelli make Oxford useful to the mass of its population. It would be of little use to the lagging progress of Italy even if Chrysoloras were again to teach Greek in its universities. Euripides and Thucydides cannot make power looms and spinning-jennies; for these Watts and Arkwrights are required. A Poggio may discover copies of Lucretius and Quintilian, without thereby producing a result equal to that of the smallest discoveries of a Stephenson or a Wheatstone. When will our schools learn that dead literature cannot be the parent of living science or of active industry? I do not underrate classical learning as an elegant accomplishment, or as a branch of human knowledge; I can rejoice as much in a good thought from Plato, or a happy allusion from Aristophanes, as I can in hearing a discussion on the philological affinities of the Indo-Germanic tongues; but I cannot understand why our sons of industry, destined to reap its harvests, should be placed in its fields of corn, having only been taught how to cull the poppies. "The great desideratum of the present age," says Liebig, "is practically manifested in the establishment of

schools in which the natural sciences occupy the most prominent places in the course of instruction. From these schools a more vigorous generation will come forth, powerful in understanding, qualified to appreciate and to accomplish all that is truly great, and to bring forth fruits of universal usefulness. Through them the resources, the wealth, and the strength of empires will be incalculably increased."

Institutions, such as this, are not substitutes for, but supplements to, the universities. It is the industrial training which we profess, and everything else is made subsidiary to that object. Not that we do or should forget abstract science, as such, because I believe the discoveries in abstract laws are of more real benefit to industry than their immediate applications. The technical man is, perhaps, of more use to himself and to his time and generation than he who discovers the abstract laws applied by the former to the purposes of industry; but it is the abstract philosopher who benefits all time, and confers universal and eternal benefit to society.

If I have convinced you that it is of infinite importance to a nation, not only to study science as constituting the foundation on which industry rests, but to promote the advancement of abstract science, the soul and life of industry, you will readily understand the importance of institutions the object of which is to infuse this life into special departments of technology. England has too long rested on the position which it has acquired as a manufacturing nation. This position was gained when local advantages gave an impulse to our practical national mind. But now that the progress of human events has converted the competition of industry into a competition of intellect, it will no longer do to plume and pride ourselves on our power of mere practical adaptations. It is miserable to see our industrial population glorying in their ignorance of the principles on which their manufactures depend, and vaunting their empiricism, or, as they term it, their "practice." Let us waken from this delusion, unless we prefer to—

" Sit like spent and patient fools,
Still puffing in the dark at one poor coal,
Held on by hope till the last spark is out."

If England keep pace with other countries as a manufacturing nation, it must be by her sons of industry becoming humble disciples of science. At present her reliance in the "practical" or "common sense" of her population is the sunken rock directly in the course both of her agriculture and manufactures. On this subject Archbishop Whately has some excellent remarks. "By common sense," says he, "is meant, I apprehend (when the term is used with any distinct meaning), an exercise of judgment, unaided by any art or system of rules; such an exercise as we must necessarily employ in numberless cases of daily occurrence, in which, having no established principles to guide us, no line of procedure, as it were, distinctly chalked out, we must needs act on the best extemporaneous conjectures we can form. He who is eminently successful in doing this is said to possess a superior degree of common sense. But that common sense is only our *second best* guide,—that the rules of art, if judiciously framed, are always desirable when they can be had,—is an assertion for which I may appeal to the testimony of mankind in general, which is so much the more valuable, inasmuch as it may be accounted the testimony of *adversaries*; for the generality have a strong predilection in favour of common sense, except in those points in which they respectively possess the knowledge of a system of rules, but in these points they deride any one who trusts to unaided common sense. A sailor, e. g., will perhaps despise the pretensions of medical men, and prefer treating a disease by common sense; but he would ridicule the proposal of navigating a ship by common sense, without regard to the maxims of nautical art. A physician again will perhaps condemn systems of political economy, of logic, or metaphysics, and insist on the superior wisdom of trusting to common sense on such matters; but he would never approve of trusting to common sense in the treatment of diseases. Neither, again, would the architect recommend a reliance on common sense alone in building, nor the musician in music, to the neglect of those systems of rules, which, in their respective arts, have been deduced from scientific reasoning, aided by experience; and the induction might be extended to every department of practice. Since,

therefore, each gives the preference to unassisted common sense only in those cases where he himself has nothing else to trust to, and invariably resorts to the rules of art wherever he possesses the knowledge of them, it is plain that mankind bear their testimony, though unconsciously, and often unwillingly, to the preference of systematic knowledge to conjectural judgments." Practice and science must now join together in a solemn union, or the former will soon emigrate to other lands. The time is past when practice can go on in the blind and vain confidence of a shallow empiricism, severed from science "like a tree from its roots." The rudest sailor may steer his ship in the direction of a landmark, but without compass and sextant he dare not traverse the expanse of ocean. Ignorance may walk in the path dimly lighted by advancing knowledge, but she stands in dismay when science passes her; and she is unable to follow, like the foolish virgin having no oil in her lamp. Depend upon it, an empirical knowledge of practice is not the way now to succeed in the struggle of individuals, or in the struggle of nations. Intellect is on the stretch to get forward, and that nation which holds not by it will soon be left behind. For a long time, practice, standing still in the pride of empiricism, and in the ungrateful forgetfulness of what science has done in its development, reared upon its portal the old and vulgar adage, "an ounce of practice is worth a ton of theory." This wretched inscription acted like a Gorgon's head, and turned to stone the aspirations of science. Believe it not! for a grain of theory, if that be an expression for science, will, when planted, like the mustard seed of Scripture, grow and wax into the greatest of trees. The pressure and difficulties of the age, and the rapid advancement of intellect in continental nations, have been the Perseus to cut off this Medusa's head from the industry of England, and to fix it on the shield of Minerva, who turns to stone such as still believe that science should be ignored by practice; but, reversing that shield, wisely conducts those who would go further under her guidance. It is now rare to find men who openly avow, although they actually entertain, a belief in a necessary antagonism between theory and practice. Theory is in fact the rule, and practice its example. Theory is but the attempt to furnish

an intelligent explanation of what is empirically ascertained to be true, and is always useful, even when wrong. Theories are the leaves of the tree of science, drawing nutriment to the parent stem while they last, and by their fall and decay affording the materials for the new leaves which are to succeed.

I have now said enough to show you that it is indispensable for this country to have a scientific education in connexion with manufactures, if we wish to outstrip the intellectual competition which now, happily for the world, prevails in all departments of industry. As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they now are.

MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied
to the Arts.

THE
RELATIONS OF NATURAL HISTORY
TO
GEOLOGY AND THE ARTS.

A LECTURE INTRODUCTORY TO THE COURSE TO BE DELIVERED
DURING THE SESSION 1851—1852.

BY
EDWARD FORBES, F.R.S.



LONDON:

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1851.



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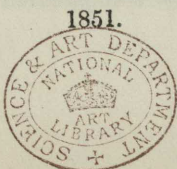
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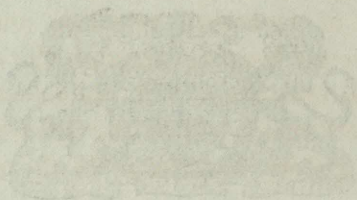
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RELATIONS OF NATURAL HISTORY

TO THE ARTS.

A FURTHER DISCUSSION TO THE COURSE OF THE LECTURES
GIVEN THE WINTER 1881-1882.

BY
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1882

NATURAL HISTORY is a vast and continually extending science. It embraces Zoology, Botany, and much of Geology. The sections of it are subdivided into studies, each of which, if pursued to its full development, would more than occupy a life-time. No single man can, in the present state of knowledge, grasp the details of all the natural history sciences, or even of one of their great sections. But the principles that pervade all are the same. The same laws govern the animal and vegetable kingdoms. The same laws regulated the phenomena of animal and vegetable life through the geological past that now regulate them in the historical present. That such is true is for the naturalist to demonstrate. The zoologist, the botanist, and the geologist contribute the elements of the demonstration, but the great pervading principles of the entire science demand a combined study of the three kingdoms of nature. The task assigned to me in this Institution is the exposition of these principles; their illustration; by examples drawn from existing and extinct forms of life; and the teaching of such details of zoology and botany, recent and fossil, as are necessary to the accurate conduct of geological research, and have thereby a practical and economic bearing, through the certainty they give to geological determinations. A second and distinct duty, hereafter to be performed, will be the illustration of the application of natural history knowledge to the arts and manufactures.

Of all the departments of the educational system adopted in this Institution, mine is apparently the least practical. The chemist, the metallurgist, the mechanician, come directly into contact with the arts and their votaries. The miner furnishes the materials from which so much of the riches of England is derived. The geologist investigates the structure of the country,

and thus gives certainty to the operations of the engineer, developes new sources of mineral and agricultural wealth, and prevents the expenditure of capital in wrong directions. All men understand why the manufacturer and artizan are indebted to the chemist and metallurgist, whose obligations to the miner and the geologist are too evident not to be freely acknowledged by themselves and those who benefit by their pursuits. But the naturalist seems to work apart from practical men. His duties are performed behind the scenes, and make no conspicuous show. His share in the work can be fully appreciated only by the geologist, whose requirements necessarily lead him into the palæontological laboratories. Like a labourer among the foundations of an edifice, he is unseen by the crowd who admire the beautiful superstructure, though without his labour the building would be unsafe and incomplete. It needs but a brief argument to prove this to an intelligent audience.

That geology is an essential element of a scientific mining education is obvious at first thought. That natural history should be, may not seem so evident to persons as yet unversed in geology. That palæontology is an essential element of geological science, no one who is acquainted with the rules by which the relative ages of sedimentary rocks are determined will deny. And that palæontology, apart from natural history, is empirical and false, and has no claims to the dignified title of science, every intelligent student of organic remains will maintain. Therefore, the teaching of the study of fossils in this Institution is to be conducted with constant reference to and comparison with living organisms; for by no other method can we hope to gain an insight into the history of the manifestations of life during the geological past, such as is necessary for the truly scientific, and, consequently, *safely practical* study of geological science and its applications.

The value of natural history as an educational science has been but partially recognized in Britain. In our schools and colleges, the chief cultivation has been directed to the nurture and training of the memory, the reasoning powers, and taste; not always by the most judicious methods. Observation, a faculty upon the correct exercise of which the value of the others

in a great measure must depend, has been neglected or even entirely ignored. Yet to observe truly, to note accurately, are surely qualities of essential importance to the well-being and future prospects of every youth. The successful progress of a man through life, the weight attached to his statements, must, in a great measure, depend upon them. The simplest, easiest, and most beneficial method of cultivating the observing powers lies in the acquirement of the methods and practice of the natural history sciences. Ignorance alone could have excluded them from recognized courses of education. Though partly taught in some of our Universities, it is as branches of knowledge usually in connexion with the enlightened profession of medicine, and not on account of their value in educational training. Of late, however, there has been a tendency to rectify this. Oxford and Cambridge have recognized, in theory at least, the right of natural history to share in their honours. Their younger sister, London, with the timidity of youth, has hesitated to pronounce in its favour. In the metropolitan colleges, and the universities of Scotland and Ireland, the natural history sciences are taught by able professors; but the total number of their unprofessional disciples is small, and cannot be said to be increasing. In schools of lesser grade they assume, when professed to be taught at all, the form of intellectual recreations; not that of exercises, and strengtheners of the mind of the pupil. The time, I trust, will yet come when every student will be required to educate his observing powers through the agency of these delightful branches of study.

The earliest efforts of infant intellect are directed towards the observation of natural objects. Animals, plants, minerals, are collected by the schoolboy, who delights to note their shape and qualities, and rudely to compare and classify. But the thirst for natural knowledge thus early and unmistakeably manifested is rudely quenched by unpalatable draughts of scholastic lore, administered too often by a tasteless pedagogue, who, blind to the indications of a true course of education, thus plainly pointed out by human nature, developing itself according to the laws of its own God-given constitution, prunes and trims, binds and cramps the youthful intellect into traditional and fantastic shapes;

even as the gardeners of a past age tortured shrubs and trees into monstrous outlines, vainly fancying to improve their aspect, arresting the growth of the spreading boughs and the budding of the clustering foliage, mistaking an unhealthy formality for beauty. Far be it from me to disparage the educational value of the glorious literature of Greece and Rome, or to withhold due honour from the many able and learned men who give dignity to their profession as educators. To them I would appeal for the rectifying of the evils of a one-sided education. I would implore them, in the name of Aristotle, the greatest of naturalists, and most admirable of observers—how great otherwise none knows better than they do—to avail themselves of that science upon which he laid so much stress, and through it to cultivate those tracts of the mind of youth that now lie fallow and unproductive.

I speak thus strongly respecting the neglect of the sciences of observation in the ordinary practice of education in England, because it is too probable that in it lies one of the chief difficulties with which schools of applied sciences will have to contend in the outset. The rudiments of science should be taught elsewhere. The student should come prepared with a groundwork of elementary training, which there is too much reason to fear, in the present condition of schools and schoolmasters, he will have great difficulty in obtaining. The training for scientific study should be effected in preparatory schools. The teaching here should consist in the communication of scientific knowledge, and in the elucidation of the applications of it. But we do not despair. The events of this year have gone far to awaken Englishmen to the consciousness of the dignity that is inherent in those pursuits which have made their country so powerful among nations. The union of practice with science is the surest way to keep her strong position. Through the operation of well-devised educational establishments only can that union be cemented, and future results secured.

In the scheme of education adopted by the School of Mines it will be observed that palæontology is regarded as inseparable from natural history. I have already said that the study of

organic remains, conducted independently of the study of living organisms, is essentially empirical and injurious to science. The value, the interest, the scientific and practical importance of fossils, depend entirely on the knowledge of their true nature, which we gain through a comparison of them with their existing homologues and analogues. That comparison cannot be understood unless we make ourselves acquainted with the habits and organization of the living types with which fossils must be compared. There are now nearly 30,000 kinds of fossils known and described; these have been discovered in formations of all epochs. Some of them are the remains of beings that lived at immeasurable distances of time,—some of them are the skeletons of creatures that flourished along with the ancestors of species now existing. Yet all researches hitherto made have gone to show that every form of extinct life was a member of the same great series of beings with those which now inhabit our world,—that the laws of organization and the laws of life were the same in the primeval epochs of Preadamite time as now,—that the same great universal thought has uniquely pervaded the one great creative action,—that the repeated manifestations of creative power during successive ages have ever announced the one consistent idea.

It is not an uncommon fancy to suppose that naturalists are occupied entirely with the naming and describing of the kinds of animals and plants; that, provided they can enumerate in clear though technical language the characteristics or features of a being submitted to their examinations, usually in the state of a preserved specimen, and, on discovery of the species being one hitherto unnoticed, give it a name by which it may be remembered by their brother naturalists to the end of time, or thereabouts, they have attained all their aim, and fulfilled all their ambition. This notion of their duties and offices is a libel. It takes note of only a fragment of their labours. To name and describe are but to enrol an object, with a true spelling and clear definition, in the great dictionary of science. Words in dictionaries are exhibitions of the raw materials out of which literature is made; and species arranged in zoological and botanical systems are orderly and beautiful displays of the raw

materials of natural history science. Words may be wasted, and species misused. But the study of species, which is the basis of all natural history science, does not take note merely of their external or even their internal organization. It deals also with their relations to conditions in time and space. It seeks out the epoch of their first appearance, and traces them through their diffusion under favouring, or limitation and final extinction under unfavourable influences. It searches for the causes inherent to their organization, by which, of two similar yet not identical creatures, the one has the power to battle with varied and very different forces, to maintain a vitality that braves the duration and complicated arrangements of several successive epochs, and, daring alike the freezing cold of the poles and the feverish warmth of the equator, to spread its individuals over more than half the world. Whilst the other, distinguished, it may be, from its congener by some apparently slight and useless difference,—though the mark be an indelible brand by which nature has stamped that member of her flock, and that one only,—is incapable of assuming protean variations, or of enduring even a slight change in the physical conditions under which it first appeared. It enjoys a fleeting existence during a short segment of time,—dies out ere it has spread beyond a mere speck on the earth's surface, disappearing never to reappear;—perchance, if it belonged to some primeval fauna, never to become known to man, with all his research, unless some bony or shelly framework gave consistence to its otherwise perishable substance.

But so to deal with our subject, so to work at natural history, how can we proceed without the aid of geology? It is plainly impossible. From the moment we recognise a consideration of the relation to time and space of species and genus as an essential element of a right and full understanding of them, from that moment the naturalist calls in geology to his aid. And how is geology to help him? The pure geologist,—the inquirer into the earth's physical features at the different stages of its eventful history, and into the probable nature of its internal constitution and the causes of the inequalities of the outline of its crust,—the pure geologist cannot aid him, but, in his turn, rather expects aid from the naturalist. For the

geologist has been taught, by his own experience, that without an investigation of the life-manifestations at successive epochs his science is fragmentary and incomplete. But the mere describing and cataloguing, the casting of them in established zoological and botanical moulds, is as likely to mislead us as to help. Such a process has misled. Half the sins of premature speculation so often called up, like filmy ghosts, to frighten incipient geologists from the beautiful science they would follow—the charges of crudeness, hastiness, vagueness, inconsistency and inaccuracy brought against geology—have arisen from this mode of attempting to misconduct scientific inquiry. The geologist collected fossils without sufficient notes, and without a notion of their zoological or botanical value; he transmitted them to the zoologist or botanist, who examined them without caring to know whence they came, under what conditions they were found, or who were their associates. It was like the author mentioned by the novelist, who, when called upon for an article on Chinese metaphysics, read up China on the one hand and Metaphysics on the other, and combined his heterogeneous knowledge in a wordy and well-sounding but empty disquisition. The time for such manner of work is going—has gone. The naturalist who examines fossils, if he would understand them, must study and practically acquaint himself with the principles and facts of geology. The naturalist who studies living beings, if he seek to grasp the philosophy of his science, must work among the remains of extinct creatures also. Geology must become an element of his studies. There was a time—not very long ago—there may be a few holders by it yet—when it was supposed that to be a zoologist a knowledge of comparative anatomy was superfluous; that to be a botanist no acquaintance with vegetable physiology was required. That day is gone, or expiring. The man who would now maintain such a state of things to be science is listened to with a smile, not argued with; and so will it be with all who pretend to investigate the phenomena of distribution, and the laws which determine the limits of genera and species, without a knowledge of geology.

On the principle that there is no palæontology without natural history, that there is no natural history without geology, the re-

lations of living to extinct forms have been borne in mind in all the arrangements of this Museum, and in all the duties of those to whom the charge of the fossil collections, made by the geological survey, has been assigned. Moreover, in order to carry out this view to its fullest extent, the officers of the palæontological department are required to take the field when investigations demand their presence, and to study the occurrence of organic remains in the rock, as well as in the cabinet. To do this they must necessarily make themselves familiar with the practice of geological research. They must learn to appreciate the exact bearing of physical and mineral conditions on organic remains. Such, too, is clearly the method by which a knowledge of palæontology of practical value to the mining student can be acquired.

In conducting the business of this class, I look forward to the holding of field-excursions, regarding them to be quite as essential as lectures for the instruction of the student, who to benefit by his studies must become a practical fossilist, and learn to observe carefully fossils *in situ*, and appreciate on the spot the evidence afforded by their associations. During the progress of our winter-courses this can be done effectually in the neighbourhood of London, or by means of the facilities of transport afforded by lines of railroad. I trust that before the end of this session a compact band of undaunted investigators, belted, strapped, and bag-bearing, armed with stout hammers and sharp chisels, under the veteran generalship of our director-in-chief, and officered by my mineral and geological colleagues and myself, will make the rocks shake and yield up their treasures for many a mile around the great metropolis.

In teaching the natural history of organic remains, we shall enforce the practice of the observation of them mainly through British examples. The principles of the study shall receive a wider range of illustration. But to learn details surely, we must acquire our knowledge through that which is most precisely known. We have abundant materials in this Museum for the minute investigation of the fossils of an area in a geological sense probably the most important and typical of provinces of the earth's surface. The value of the collection does not depend merely on the number of species or beauty of speci-

mens, though in these respects we have much to boast of; it is due to the minute information preserved in our records respecting the history of individual specimens. Every fossil collected during the operations of the geological survey has a value far beyond any accident of fineness or rarity. It has been selected especially and precisely in elucidation of a geological fact. It is a lasting and ever-consultable memorandum of a geological observation. Its locality, its associates, the abundance or scarcity of individuals of the species at the spot and in the stratum where it was found, the mineral character of the rock itself, the condition of the specimen—whether indicative of entombment when alive, or of death before becoming imbedded, or of transport before reaching the spot where, invested with sediment, it became immortalized in stone,—all these points, essential to an accurate, to a scientific knowledge of the fossil, have been carefully noted and recorded; and the specimens incorporated with the survey collections are worthy associates of them. We know who collected them, and how they were collected; and before they find a place in our cabinets their history has been traced and certified.

Such materials give confidence to the student. He feels that through them he may acquire information calculated to assure him in his after researches; he imagines for himself a safe type, a standard of comparison by which to test less perfect data. If his fate should lead him to undertake geological, mining, or exploring adventures in distant and little known lands, he will find himself far better qualified to draw conclusions respecting the age and position of fossiliferous strata than if he had come to the inquiry with a vague general knowledge such as he might gather from the inspection of a universal collection; for an intimate acquaintance with the fossils of all regions could not be acquired by him even during many years. He has learnt not only *how* to observe, but also *what* to observe; he has gone through that wholesome training which monographic exercises in any of the divisions of natural history invariably give. Without it, zoologists, botanists, and geologists must be content to take place among mere declaimers and talkers about things, which, in the absence of practical knowledge, all possible reading and lecture-listening will fail to make them understand,

The collections of organic remains displayed in the galleries of this museum are not of interest to the student only, they have a public value: they bear testimony to the correctness of our knowledge of the geological structure of the British Islands; and, where they coincide with the operations of the geological survey, present the minutest evidence of the age and features of the strata explored, as far as fossils can afford such evidence. And as the economic value of geological observations must ever depend on their strict accuracy—on the confidence that may be placed in them by those who would invest capital or prosecute researches on account of their faith in data officially laid before the public—such tangible proofs, open to the most severe scrutiny, as collections of organic remains made on the spot by the officers of the survey, must have a practical importance, upon which too much stress cannot be laid.

In a country where riches are a title to high esteem and power, any branch of science that has no direct influence upon money-making is likely to be held in low estimation by the unenlightened. The meaning attached to the word *practical* in England is often nearly synonymous with *money-producing* or *money-saving*. Although I would be the last person to maintain that scientific establishments should be supported by the nation, or scientific researches respected, mainly on account of such recommendation, I am not one of those who would separate science from the ordinary pursuits of men, or who would desire to see philosophers withdrawing themselves from the multitude, by keeping their thoughts unmingled with the meaner aims of the crowd. When science, provided she be mindful of her honour, and make no sacrifices of her love of truth, serves as the handmaiden of even the humblest of arts, her dignity gains in lustre, and her familiarity breeds respect. There is no department of science without some ties with the common business of life. Even palæontology may have a direct as well as an indirect influence on commercial enterprises. An example or two, out of many, may serve as an illustration.

Not long ago considerable funds were spent in a district in the west in a useless search for coal. The adventurers, ignorant of geology, had set to work in dark Silurian shales, among the oldest of stratified rocks, and far beneath our car-

boniferous strata. Their mineral aspect, however, resembled that of certain coal-shales with which the miners were familiar. Had they possessed even a slight acquaintance with organic remains, they would have abandoned their profitless experiment at the very commencement; for the shales in which they were working were charged with graptolites, extinct zoophytes, which do not range higher than the lowest fossiliferous group, and the presence of which indicated the true character of the strata beyond question. The fossils did not escape the notice of the miners. They collected them, and grew the more confirmed in their mistake; for, unacquainted with the differences, they mistook them for coal plants. They might have bored through the earth's centre without coming to the treasure they sought; their only chance of reaching it was by perforating quite to the antipodes.

In a second example I was myself personally concerned. Some years ago, when as yet but a student attending the geological and mineralogical lectures of Professor Jameson, I opposed by letter in a provincial journal a mistaken enterprise upon which much money was unfortunately spent. The object of it was to sink through the old red sandstone, with the hope of reaching coal, in a district where such a search was hopeless. The parties engaged were confirmed in their intentions by the advice of practical coal-miners well acquainted with the collieries of the north of England. These men argued, that since there was limestone and sandstone similar to those rocks associated with coal, and overlying it, in the districts where they had worked, therefore the strata were the same, and coal should be found. I pointed out, chiefly from the evidence of the fossils contained in the limestone overlying the sandstone, that the rocks on which they proposed to operate were only like to, but not identical with, those to which they were compared. I told them,—the warning was proffered in vain,—that they were throwing away their money. One of the shareholders, an intelligent man, and a reader of elementary works on geology, replied to my objections by attempting to meet them on scientific grounds. In some old-fashioned books it used to be asserted, that shells of the genus *cardium*,—in plainer language, cockle-shells,—when

found fossil, are characteristic of tertiary strata. "Now," wrote my opponent, "cockles abound in the limestone in question, therefore it is tertiary, and the carboniferous strata must lie beneath." He had mistaken certain forms of *terebratula*, shells of a very different order, for cockles; a very unfortunate mistake, for the error was persisted in, and much good gold turned into irredeemable dust.

I have cited these instances because they not only show how serious an error, leading to considerable pecuniary losses, may be committed in consequence of ignorance of science, but also are examples of the danger of inaccurate or fancied knowledge. In both these cases the fossils were noticed, but, through ignorance of these distinctions, altogether mistaken.

There is much popular palæontology abroad, as likely to mislead as to guide. The practical value of this section of natural history depends upon its certainties, and not upon its uncertainties. In the former class may be placed the determination which fossils afford of the origin of rocks, whether they be marine or estuary or fresh-water deposits; of the relative ages of sedimentary strata; of the indications they give of the climate of different epochs; of the information they contribute respecting the ancient physical geography of our globe; of the testimony they bear to the unity, harmony, and benevolence of the Divine scheme of creation,—the same during incalculably distant centuries of primæval time as now.

Under the head of uncertainties may be ranked theories of transmutation of species; of progression towards perfection; of universal diffusion of species at ancient epochs; of the retrograde development of animal and vegetable forms in time; of original perfection and subsequent degeneration; of original generalization of specific types, and subsequent specification; of differences in the physiological habits of creatures anciently and now. All these notions are hypothetically or theoretically advocated, more or less, by men of science at the present day. All of them, it seems to me, are at best inductions from insufficient data. They may or may not be true, but at present, as we may see by a glance at the comparative extent of our knowledge of existing and extinct forms, we are not in a con-

dition to come to a decision on the important questions they involve.

The collections of fossils displayed in the cabinets of this museum are highly illustrative of the great truths of geology, and are arranged so as to convey instruction on the fundamental principles of the science. The fossils of each formation,—in stricter language, the creatures of each epoch in the preadamic history of the earth's formation,—are grouped together, and each group is displayed in strict geological sequence,—in order of superposition of strata. Whoever studies these collections carefully may gain a clear conception of the nature of the proofs afforded by natural history of the vast duration of the earth, and the series of epochs, each characterized by a distinct creation of organized beings, that have preceded the present condition of animated nature.

Although in the commencement of our educational efforts we can scarcely hope to embrace all the subjects that spring out of the arrangements of this Institution, it behoves us to look forward to the utilization in other directions than that of geological science even of its natural history resources. There is a great blank yet unfilled in the teaching of the numerous applications which may be made of natural history to the arts. Charming as are the exquisite examples of ceramic, vitreous, and metallic manufactures collected in our Museum, we cannot but feel that the workman, however fine his natural or acquired taste may be, is unaware of the vast variety of beautiful shapes and designs that lie unused in the treasury of nature. The aiding of the manufacturer in the perfecting of his works is one of the aims we profess. The chemist can teach him how to improve his materials, or furnish him with new substances and new pigments to use in his art; the metallurgist can show him those metallic compounds that can give the finest effect to his castings; the mineralogist and geologist can open out fresh stores of ore and earth suitable for his operations. Cannot the naturalist also come forth with friendly aid, and render some good service?

The relations of natural history with the arts are of two kinds, either illustrative or suggestive. To the first belongs the inquiry into the nature and sources of the numerous pro-

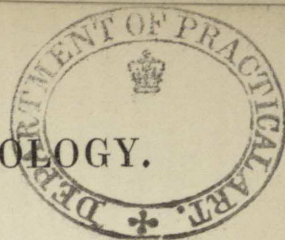
ducts derived from the animal and vegetable kingdoms, and applied, or capable of being applied, as direct materials for arts and manufactures. A more perfect acquaintance with old and a discovery or indication of new materials adapted for the exercise of human skill and workmanship may thus be attained. But the naturalist may render higher and at the same time as practical services to the craftsman, by furnishing out of the endless store of beautiful objects that are rendered familiar to him by his scientific pursuits sources of new and exquisite design,—fancies originating in the teeming brain of nature,—God-born thoughts, that become manifest in living shapes,—all consistent,—never jarring,—in every part admirably adapted to each destined purpose. Now the laws of these adaptations and harmonies, the proportions by which the beauty of living things is maintained, the ideas by which similar forms have been grouped in nature, and, though like exceedingly, yet wondrously dissimilar,—these are among the earnest studies of every philosophical naturalist. Surely out of such studies lessons applicable to art may be derived? What is ornamental art but the isolation and embodiment in works of human skill of the beauty that is diffused through all the works of God? And that beauty lies, not merely in the bulk of objects, nor on their surface, but is as manifest in every part and atom composing them as in the combined whole. It is in itself composite; the combination, not of lesser, but of minuter beauties. To imitate,—to approach,—we must attempt a like arrangement, in order to obtain the same exquisite result. And how, except through earnest and scientific study, can we attain the knowledge that shall enable us to discover the pathway leading towards perfection?

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MUSEUM OF PRACTICAL GEOLOGY.



Government School of Mines and of Science applied
to the Arts.

INDUSTRIAL INSTRUCTION

ON

THE CONTINENT.

(BEING THE INTRODUCTORY LECTURE OF THE SESSION 1852-1853.)

BY

LYON PLAYFAIR, C.B., F.R.S.



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1852.

MANUAL OF PRACTICAL GEOLOGY

Colburn's School of Mines and of Mineralogy
and to the study of the history of the earth

INDUSTRIAL GEOLOGY

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1852

The Intellectual Element of Production on the Continent.

By DR. LYON PLAYFAIR, C.B., F.R.S.

IN two former Lectures on the subject of Industrial Instruction, I alluded generally to the efforts made by Foreign States to instruct their populations in that knowledge of natural forces which is so necessary at a period of civilization when the competition of industry has become a competition of intellect. It is, indeed, natural, that a perception of the necessity of industrial instruction should arise in those countries where the natural impulses to productive labour are either wanting or deficient, and where knowledge became essential to overcome the special resistances to manufacturing progress. To study the character and extent of the technical institutions abroad was, at the same time, to study not only their effects but also the causes which had led to their establishment; and I have, therefore, employed the short vacation, between our sessions, in visiting some of the principal institutions in Denmark, Prussia, Saxony, Austria, Bavaria, Baden, and France, for the purpose of making myself acquainted with the modes of instruction pursued in them. While endeavouring to communicate to you some of the impressions received by myself, it ought to be stated at the outset that the examination has been far from complete: the time spent by me in each of the institutions, though as much as I could give, was not always sufficient for a thorough investigation into the systems of instruction; besides which I visited them as a simple traveller, unarmed with any official recognition or aid, and depending for the requisite facilities of investigation only to an extensive acquaintance which I have the honour to enjoy in the countries referred to.* You will, therefore, understand distinctly, that my examination of the Technical schools abroad having no official character, has no claim to official completeness. Nor, in the short time at my disposal, could sufficient information have been collected to lay before you, had it not been for an extraordinary amount of courtesy and attention on the part of the directors of these institutions, and, in several cases, of the departments of Government with which they were connected.

Before entering into any details of the systems of instruction in foreign industrial institutions, it is requisite to show why they were required abroad, and why they are now necessary at home. In discussing this

* In the Appendix, under the head of each country, will be found the names of some of those who furnished me with information.

argument in its general bearings, I may have to repeat views urged upon former occasions ; but, as truths must be repeated until their consequences are realised, this is, perhaps, of little consequence, and will meet with a ready excuse.

Production, as understood in political economy, consists in the formation of utilities out of objects, which, either from their position or form, were of little use until subjected to the operations of industry. The principles involved in extractive, manufacturing, and even in distributive industry, are very similar in character, and involve the same factors. In industry, we can form utilities, but we cannot create properties. We can bring sand and soda together in the heat of the furnace, and we have formed the transparent body glass ; but we have only used properties already existing in these materials, the acid character of the one and the alkaline character of the other having been employed to effect a chemical combination. In no one instance in production do we add a single property to matter, but we combine properties and create utilities. The success of a producer depends, therefore, to a great extent, upon his perceptive or empirical knowledge of properties and his power of using them so as to form utilities. But nature is very bountiful, and, in addition to properties embodied in matter, furnishes us with powers by which we can abridge human labour and more effectually overcome natural resistances to combination. Uncivilized tribes may, and often do, by observation, acquire a knowledge of properties equal to that enjoyed by nations more advanced ; but they rarely understand those natural powers which form the strength and wealth of States that promote their study. Dacca and Chunderee can, by manual labour, make muslins better than our own ; but the power loom and the spinning jenny were reserved for a nation which had studied the laws of mechanical science. Penelope required twelve slaves to prepare corn for her small household ; while, as Chevallier remarks, the mill of St. Maur, with twenty men, grinds corn daily for the support of one hundred thousand soldiers.

Production involves as its factors, primarily, the material to be converted into an utility ; then, the labour employed in the conversion ; and, lastly, capital, which has been compared to the blood corpuscles, because it imparts vigour and activity to the vital processes, without itself taking direct participation or undergoing assimilation. The first factor—the raw material—is common in excellence to all producers, differing only in the relative cost of extraction and transport, or increased in price by arbitrary fiscal regulations. As locomotion improves, the local advantages of the country to which the raw material is indigenous become of less importance as an element in production ; and industrial competition depends more upon labour—the second factor—than upon the first. This is certainly the case, or raw cotton could not be imported from America to be exported as calico. Malachite, sand, and wool could not come from Australia to go back as copper, glass, and broad cloth ; nor could Dutch madder reach us to return to Holland as printed gingham, or horse-hair and fat from Buenos Ayres and Russia to be returned as hair-cloth and soap. All this shows that the superiority of labour in one country does more than

compensate for the disadvantages arising from increased cost in the raw material.

Labour, however, is of two kinds—corporeal and mental, or, as Mill calls it—muscular and nervous. Mere muscular labour is to be had in all countries : the Egyptians, with their hoes and baskets, are found to be as good excavators as those we sent over with barrows and spades ; but Egypt had to import the mental labour of a Stephenson before it ventured to produce a railway. The fact is every day more apparent, that mere muscular labour, in the present state of the world, is little better than raw material, and that both these are sinking in value as elements of production, while nervous or intellectual labour is constantly rising. The whole of industrial competition is now resolved into a struggle to obtain a *maximum* effect by a *minimum* expenditure of power. But this power is derived from natural forces, and not from brute strength : mental labour has engrafted itself upon muscular effort, and, by a healthy growth, has reduced the size and relative importance of the latter. Every new acquirement in the knowledge of natural forces is the acquisition of a new sense, which may be applied to production ; and as every substitution of a natural force for muscular exertion depends upon a knowledge of the former, it surely requires no argument to prove, that the economical application of it must rest upon a perceptive and not merely empirical knowledge ; or, in the language of the Wise King of Scripture, “If the iron be blunt, and we whet not the edge, then must we put to more strength ; but wisdom is profitable to direct.”

To this portion of the argument I have again to return ; but an allusion to it was necessary, because these were the considerations which forced foreign countries to give an industrial education to their populations. Foreign States, partly from a deficiency of extractive labour, partly from an actual want of resources, were poor in the raw material or immediate means of production, and had, therefore, to rely chiefly on the proximate means. In the absence even of material for constructing machinery, it was not to be expected that tools, those essential proximate means of production, should quickly arise in an early stage of competition, although their economical application, when obtained, became of vital importance. Hence arose the obvious political necessity of developing rapidly the knowledge of natural powers, because these can only be effectually applied when fully understood.* This knowledge became, indeed, an intellectual tool of the

* Sir John Herschel puts the argument very happily as follows :

“ If the laws of nature, on the one hand, are invincible opponents, on the other, they are irresistible auxiliaries ; and it will not be amiss if we regard them in each of these characters, and consider the great importance of a knowledge of them to mankind :

“ I. *In showing how to avoid attempting impossibilities.*

“ II. *In securing us from important mistakes in attempting what is in itself possible, by means either inadequate or actually opposed to the end in view.*

“ III. *In enabling us to accomplish our ends in the easiest, shortest, most economical, and most effectual manner.*

“ IV. *In inducing us to attempt, and enabling us to accomplish, objects, which, but for such knowledge, we should never have thought of undertaking.*”

greatest importance in a country which had yet to acquire experience. In our own land, the rapid development given to production by our richness in natural resources raised at the same time a vast amount of experience, and art advanced before science. This experience was often produced by trial and error, and was attained by great expenditure of time and capital; but, when arrived at, afforded much help to production. Hence we see many producers in our own country, practising their arts by the aid of empirical experience only, little guided by scientific laws. Hence also has arisen an overweening respect for practice, and a contempt for science; as if man could better use the powers of nature by stumbling against them in the dark, rather than by reverentially seeking them in the open light of day. But continental producers, being behind us in the race of competition, and having industries to create, preferred to profit by our empirical experience, and then pass us by their applied knowledge; for they have virtually adopted, as a principle of State, the aphorism of Bacon, "The knowledge and power of man are coincident; for, whilst ignorant of causes, he can produce no effects. Nature is only to be conquered by submission; for that which in speculation stands for the cause, is what in practice stands for the rule."

Perhaps, until lately, the balance of advantages was in favour of this country; for, with our cheap natural resources in material, and its difficulty of transmission to other countries, the practical aptitude of our population in availing themselves of the benefits of experience, and the power of our capital in directing labour and importing intellect, when that was not to be found sufficiently cultivated at home, we have had impulses given to production which have communicated to it an impetus sufficient to carry it for some time over the obstacles raised by the superiority of the intellectual element of labour abroad. But that a rapid change is passing over the world has long been seen by statesmen and by all thinking men,—a change which must effect immense alterations in the productive powers of all nations. In the words of Prince Albert, "Whilst formerly discovery was wrapt in secrecy, the publicity of the present day causes that no sooner is a discovery or invention made, than it is already improved upon and surpassed by competing efforts. The products of all quarters of the globe are placed at our disposal, and we have only to choose which is the best and cheapest for our purposes, and the powers of production are entrusted to the stimulus of competition and capital. . . . The distances which separated the different nations and parts of the globe are gradually vanishing before the achievements of modern invention, and we can traverse them with incredible ease. The languages of all nations are known, and their acquirement placed within the reach of everybody. Thought is communicated with the rapidity and even with the power of lightning." These circumstances are daily lessening the value of mere experience,* which arising in

* By the term *experience* in this lecture, I allude only to the empirical knowledge which arises in the growth of practice; it is not used in its true metaphysical or scientific meaning.

one country soon becomes the property of another. For many years, foreign States, acting upon the facilities of communication, have expended annually large sums in sending highly enlightened men to our country for the purpose of culling from our experience, and of importing it into their own land; and we see the effect of the experience, thus readily acquired when united with the high development of mental labour, in the rapid growth of new industries abroad. We still hold to mere experience as the sheet anchor of this country, forgetful that the moulds in which it was cast are of antique shape, and ignorant that new currents have swept away the sand which formerly held it fast, so that we are in imminent risk of being drifted ashore.

In fact, this is the great question at issue between England and foreign States. With us there is a wide-spread jealousy of science, and a supposed antagonism between it and practice. Mere empirical experience is of slow growth, and, after all, is only adapted for the particular conditions in which it was attained: it is a crutch which will support a lame man, but will not suffice to enable him to run a race; it resembles in its growth the slow propagation of an unaided flora throughout a land, which might be quickly disseminated, if science were allowed to gather its seeds and throw them broadcast over the country. It is only experience, aided by science, that is rapid in development and certain in action. In this country we have eminent "practical" men and eminent "scientific" men; but they are not united, and generally walk in paths wholly distinct. From this absence of connexion there is often a want of mutual esteem, and a misapprehension of their relative importance to each other. The philosopher is apt to undervalue the dignity of productive industry, while the practical man sees, in the absence of utilities, only the visionary speculator. Hence the former too often stands apart in self-reliance on his usefulness to the world, and like Themistocles, when asked to play, is inclined to reply, "Though I cannot fiddle, I can make a little village a great city." Abroad, the scientific element of production is carefully nurtured, because the truth is there fully recognized, that nothing is so fertile in utilities as absolute abstractions; but it is known also to be essential to industry, that there should be a race of men to translate these abstractions into worldly utilities, and who can solicit nature, in language understood by her, to lend her powers for the fulfilment of practical ends. The creation of this class of men was, as has been shown, a necessity of foreign competition; for, without this superiority in the intellect-element of labour, it was impossible to overcome our advantages in the cheapness of material and in the abundance of capital.

But this forced perception of the necessity for industrial instruction has enabled the continent to seize the *growing* element of production, while we are left in possession of the *decreasing* one; and while we continue to rely upon local advantages and acquired experience, we allow a vast power to arise abroad which is already telling against us with wonderful effect. It is most essential that we should furnish this element of strength to our producers, and not imitate the rustics in the fencing school described by

Demosthenes, who always after a hit guarded the part that was struck, but not before.

In raising the intellect-element of production, continental States have passed through grave errors, from which they have only lately escaped; and it will be useful for us to profit by and avoid them. To understand the evils into which a wrong direction of education led them, it is necessary again to refer to the separation between abstract and practical science. In former Lectures I have endeavoured to show how important it is to a nation to develop abstract science; it is not, therefore, likely that I shall be misunderstood as depreciating it in the remarks which I am about to make. Rather than again urge this point, I quote the high authority of Mill from his "Political Economy."

"In a national or universal point of view the labour of the savant or speculative thinker is as much a part of production, in the very narrowest sense, as that of the inventor of a practical art; many such inventions having been the direct consequences of theoretic discoveries, and every extension of knowledge of the powers of nature being fruitful of applications to the purposes of outward life. The electro-magnetic telegraph was the wonderful and most unexpected consequence of the experiment of Oersted, and of the mathematical investigations of Ampère: and the modern art of navigation is an unforeseen emanation from the purely speculative, and apparently merely curious, inquiry by the mathematicians of Alexandria, into the properties of three curves formed by the intersection of a plane surface and a cone. No limit can be set to the importance, even in a purely productive and material point of view, of mere thought. . . . Intellectual speculations must be looked upon as a most influential part of the productive labour of society, and the portion of its resources employed in carrying on and remunerating such labour, as a highly productive part of its expenditure."

In this country we have a theoretical belief but no practical faith in these views. We have taken good care not to imitate the woman in *Æsop's* fables, who believed that a double feed would induce her hen to lay double the quantity of eggs, not dreaming that the hen would get fat and lay none at all; but we have produced nearly the same result, by neglecting to feed our philosophers, and we are surprised that the golden eggs of discovery are now so rarely laid among us.

In Germany especially, and in France also, the error was committed, of supposing that abstractions would naturally give birth to utilities, without intermediate practice to aid the birth. Hence education was made wholly of an abstract character, and the cumulation of an abstract instruction of the masses became positively pernicious. Large numbers of men were reared in abstract, physical, and mental philosophy, for whom the channels of industry offered no outlet; they naturally pressed upon the Government which had stimulated them to acquire abstract knowledge, and a gigantic bureaucracy was forced upon the State. The evil increased to such an extent that in some States 60 out of 1,000 of the population were

in Government employment. A mere university education* in abstract philosophy, or the secondary instruction of the Grammar schools, was found to be a hot-bed for the production of bureaucrats, and only indirectly useful to industrial production. The error was perceived by many, and found expression in various ways: thus Count Von Seidlitz, in leaving his fortune for the promotion of industrial education, quaintly says in his will, "I should commit a sin against the Holy Spirit if I left my money so as to induce young men to study, in order that they might continue to turn round the tread-mill of the State."† To relieve the State from an overwhelming bureaucracy, and at the same time to give a rapid impulse to the growth of manufactures, numerous channels were formed, by which abstractions might be drawn off for the support of utilities. The "Real" system of education then arose in Germany, and is now extending under this or other names to all European countries, except our own. In the schools professing this system the realities of modern life are taught in preference to the languages and customs of the classical ages. This, perhaps, too rapid transition of the secondary instruction, forced realities into the "Gymnasias" or Classical schools themselves, and these became more adapted for modern wants. The Real schools were found to act favourably in diminishing the exclusive attention to the study of abstract philosophy, but they did not suffice to give a quick impulse to industrial development; hence arose the widely extending system of "*Gewerbe*" or Trade schools, and, as the culminating points of these, the Polytechnic Institutes or Industrial Universities.

This circumstance is generally lost sight of by some modern writers of repute, who vehemently warn you to shun the poison of continental education, but neglect to tell you, that when the cause of its hurtfulness was discovered, the poison was extracted. They take the dying embers of a fire which burned for some time too fiercely, and blowing them again into life, they profess that the heat continues to be equally scorching; they tear evils out of the past, and, dressing them up in a modern garb, try to make you believe that they still live, although it is only the results effected by them that are yet seen in the passing generations: they trust to our native prejudices, and try to scare us with what Carlyle would call "the ghosts of extinct giants."

* As an instance of the extent to which abstract education is even yet cultivated, there were, in the universities of Germany and Switzerland, in the session of 1851-52,—18,810 students; of whom,—

3,450 were theologians.

6,761 jurists and economists.

4,182 medical men.

2,644 "philosophers," or students of the abstract sciences,
chiefly the mental.

1,773 unclassified.

—"Allgemeine Zeitung," 6th October 1852.

† "Ich würde eine Sünde gegen den heilig Geist begehen, wenn ich mein Geld dazu bestimmte junge Leute zum studiren zu verleiten, um den Rossmühlengang des Staats Weiter zu treten."

It is the peculiarity of the industrial system of instruction that it can scarcely over-educate a population, as is so frequently done in professions, because industry is universal and of infinite proportions. The streams which water the vast plains of industry are never too full, for by a little diversion they can be made to irrigate and render fertile new and yet uncultivated tracts. Although the channels leading from an abstract to a practical education are constantly augmented by the policy of foreign Governments, they do not exhibit any sign of being in excess, nor are the waters kept back by a deficiency of outlet. It is, in fact, almost impossible that they should be so, for after all they terminate only in the world's ocean of industry, where they are sure to be absorbed. Do we not see this in the fact that our glass-makers, porcelain-manufacturers, our calico-printers, and others, have been obliged to receive from abroad that intellectual element of manufacture which they could not obtain at home—a right policy for industrial producers, but a miserable one for the State which had neglected to cultivate it within itself?

The State does not deem it expedient to rely on a supply of sailors from foreign countries for defending its own possessions; it prefers to send out more sailors from its nurseries than our own demands require, allowing them rather to enter into foreign service than check their growth at home. We know that, though to some extent losers by this, on the whole we are great gainers. Precisely the same feeling operates with continental countries, who would rather have an excess of the intellectual element of production than a deficiency, and who do not object to the employment of that excess in England, not only because it is a premium to its growth among themselves, but also because it forms a connecting channel through which our advanced experience flows back to them in return for the intellect abstracted.

The very fact that many of our most enlightened manufacturers have intellectual foreigners to aid them in the management of their works, or in their productions, shows that the continental system of industrial instruction is producing results which require the most serious attention of those who would see our industry continue to enjoy that prominent position in the rapidly changing state of the world, which it acquired when the transition was slow, when facilities of locomotion did not exist to the extent that they now do, and, therefore, when mere experience and local advantages, aided by the occasional irruption of science, was sufficient to keep pace with the march of events. I therefore proceed to show you the nature of that instruction, so far as I can in a Lecture of this kind.*

* In the body of the Lecture generalities only are treated of; the details are frequently to be found in the Appendix. It may here be stated, that no description of Schools of Mines is given, because these have been already fully described by various authors; a memoir specially devoted to them will be found in vol. i. p. 485 of the "Memoirs of the Geological Survey, &c."

INDUSTRIAL INSTRUCTION OF PRUSSIA.

I would remind you, that the secondary education of Prussia is of three kinds ; and consists of the *Gymnasia*, or Classical Schools ; the *Real* Schools ; and the *Gewerbe*, or Trade Schools.

The *Gymnasia* teach many more *realities* than the Grammar schools of our country, but nevertheless they are chiefly classical. The *Real* schools profess a general education, like the *Gymnasia*, but substitute the modern languages for the ancient ; preserving, however, Latin, and giving more prominence than the *Gymnasia* to the physical sciences. In the provinces of the Rhine, in other words, in the chief manufacturing districts of Prussia, the *Real* schools are the best attended, and perhaps in Berlin also ; but, upon the whole, the *Gymnasia*, which are indispensable for admission to the University, still retain their high position as means of affording a secondary education ; and they hold their places more firmly since they have begun to introduce *realities* into their courses. With both these systems, however, I have nothing to do in this Lecture further than to draw attention to the fact, that the general character of all secondary education in Germany is tending towards giving instruction in the wants of the nineteenth century, and not stopping at that considered sufficient in the thirteenth, as many of our classical schools do.

The third system of secondary education, the Trade schools, is, however, directly technical in character. Pupils are not admitted into them until they are fourteen years of age, and it therefore frequently happens that they have had a *real* education previous to their admission. Every pupil, before entering them, must have had a good primary education in his own language, must thoroughly understand the elements of arithmetic, and the mensuration of plane and solid bodies, and must be able to show that he is a good free hand drawer. The course of instruction consists of two years, and the time given to each object of study is seen in the following scheme :—

SCHEME OF THE TRADE (PREPARATORY) SCHOOLS OF PRUSSIA.

UNDER CLASS (1st year).

	Hours in a week.
Planimetry *	4
Algebra, to equations of the first degree	3
Practical arithmetic	4
Physics	4
Chemistry	4
Free drawing	7
Linear drawing	9
	35

* Plane Geometry.

UPPER CLASS (2nd year).

a. Winter Session.

Continuation of algebra—trigonometry	-	-	-	3
Stereometry * and descriptive geometry	-	-	-	3
Practical calculation	-	-	-	2
Mechanics and machinery	-	-	-	3
Laboratory work, and repetitions in chemistry and physics	-	-	-	4
Mineralogy	-	-	-	2
Architecture, contract works, and plans	-	-	-	3
Free drawing	-	-	-	7
Linear drawing	-	-	-	9
				36

b. Summer Session.

Continuation of descriptive geometry and conic sections	-	3
Application of algebra and trigonometry to the solution of } questions in planimetry and stereometry—land surveying - }		3
Practical calculations (extraction of roots, logarithmic practice, } and calculations of capacities in bodies) - }		2
Machinery and mechanical technology	-	3
Chemical technology	-	4
Mineralogy	-	2
Architecture and building plans	-	3
Free drawing, modelling	-	7
Linear drawing	-	9
		36

In looking at the scheme of instruction, you will scarcely remember that these Trade schools are in fact only preparatory to the Central Industrial Institute of Berlin; but you may naturally inquire,—Have such schools arisen in the necessity of the people, or by a political perception of their requirement on the part of the Government? The answer is, that the Government only grants one half the funds necessary for their annual support, and that the towns in which they are situated must furnish the rest, and build the school-houses. No such school is founded unless upon the petition of a locality for a grant in aid; so that they are, in fact, based upon the same principles as our own Schools of Design, with this difference, that the localities do more and the Government less than in this country. There are now 26† of these Trade schools in Prussia, viz., 7 in the provinces of the Rhine, 5 in Westphalia, 3 in Prussian Saxony, 2 in Brandenburg, 2 in Pomerania, 3 in Prussia Proper, 2 in Silesia, and 1 in Posen. They are therefore situated so as to exert a direct influence on the chief industrial parts of Prussia. The instruction is not gratuitous, the charge varying from thirty shillings to three pounds annually; and yet about 1,200 scholars are every year receiving the comprehensive technical knowledge offered by these professedly elementary schools. The instruction and examinations are

* Solid Géometry.

† Two of them, however, are only in the act of formation, viz., those at Coblenz and Dusseldorf.

watched by Government, through Commissioners appointed by the Minister of Trade; and the best pupils have the privilege of passing to the Central Institute at Berlin, to which I have now to refer.

THE TRADE INSTITUTE OF BERLIN.

The Trade schools of Prussia are mainly intended for tradesmen or small producers, such as masons, carpenters, well-sinkers, millwrights, &c.; while the Trade Institute professes chiefly the instruction of engineers, civil or mechanical, architects, and managers of factories and chemical works. The foundation, however, of this Central Institute is different from all others which I have seen on the continent, and is in fact now in a transition state. Not only is its instruction wholly gratuitous, but about 50 out of its 170 pupils receive 30% annually from the Government. The annual cost of the school to the State is 7,000*l.*, of which 1,500*l.* are devoted to the support of poor pupils, and 1,000*l.* are spent in travelling expenses, both professors and students being occasionally sent to foreign countries to acquire a knowledge of recent inventions and new industrial improvements. The chief peculiarity of this institution was in its being originally confined to the education of workmen, who, in addition to the principles of their trade, were even taught their mechanical craft in extensive workshops. It is now, however, acknowledged that this was an error, and that the practice of an art can only be learned, satisfactorily, in the workshops of industry. The whole organization of the school has, therefore, been recently changed, and its instruction is now assimilated in character to that given by the other higher industrial institutions of Germany; but, as its past experience is instructive, I have described its present and former systems in the Appendix (App. A.) Now the instruction is devoted to the higher class of producers, and among its professors are the well known names of Drückenmüller, Wolff, Dove, Rammelsberg, Magnus, Wiebe, Fink, Freiberg, Pohlke, Kiss, and Boettlicher. As might be expected from men of such eminence, the character of the instruction, though eminently practical, is at the same time highly scientific. The course of instruction is for three years, and the students, before being admitted, must have a "maturity certificate" from a Secondary school, or submit to an entrance examination. Accordingly, no student comes to this Central College without being well acquainted with the elements of mathematics, physics, chemistry, and drawing. This previous knowledge is of the greatest importance, as it relieves the professors from teaching the elements, and enables them to devote their whole time to the applications of the sciences. The course of instruction extends over three years, but in the second and third years the students divide into special branches, adapted to the three divisions of (A) mechanics and engineers, (B) chemists, (C) architects and builders. The following list of subjects will give an idea of the extent of the instruction:—

COURSE I.

Hours in
a week.*

- | | | |
|-----|---|---|
| 8. | a. Pure mathematics | } Stereometry and spherical trigonometry; descriptive geometry; algebra, differential and integral calculus; analytical geometry; practical calculations. |
| 6. | b. Physics. | |
| 6. | c. Chemistry. | |
| 8. | d. Linear drawing, particularly constructions by descriptive geometry, shaded constructions, and perspective; then machinery-drawing. | |
| 10. | e. Free and architectural drawing. | |

COURSE II.

6. a. Pure and applied mechanics, illustrated by the higher mathematics.
4. b. Repetitions and specialities in physics and chemistry.
3. c. Mineralogy.
7. d. Materials used in building, and laws of architecture.

These are the courses common to all students; but, engrafted upon these, come the separate courses for the different professions.

A. For *Mechanics*.

In Course II.:

9. Machinery in an extended course; materials used in machines; separate parts of mechanism; machines used in building; composite machines; practical exercises.

In Course III.:

12. a. Continuation of machinery; steam engines and other machines driven by power; practice in projection.
- b. Railways and buildings.
4. c. Technology.
- d. Practice in the machine-workshop (3 days in the week).

B. For *Chemists*.

In Course II.:

8. { a. Chemical technology.
- { b. Analytical chemistry.
- c. Practice in the laboratory (2 days in the week).

In Course III.:

- a. Laboratory work (daily).
4. b. Machinery drawing and projections.

C. For *Builders and Architects*.

In Course II.:

8. a. Freehand and architectural drawing; projections in building, both in stone, brick, and wood.
- b. Modelling in clay.

In Course III.:

9. a. Projects, plans, and estimates for buildings.
- b. Stone cutting (6 months).
- c. Heating and warming arrangements (6 months).
8. d. Plans and contracts of factories, &c.
4. e. The machinery class (with the chemists).
- f. Modelling of buildings in plaster, wood, and stone.

These courses, except in those cases which are marked, extend over two sessions of 6 months each.

* These hours are only approximative; the workshops and laboratory employ all the spare hours which are not here indicated.

The plan of instruction in this school is, to communicate all such information as may be required by a particular manufacturer, although not directly included in the limits of his profession. Thus it is considered necessary that the chemist should be able to construct plans, make estimates, and understand the principles of machinery, in order that he may know how to express his wants to engineers or builders, and be able to see that the contracts are not excessive in price. As the instruction is given gratuitously by the State, only those students are allowed to remain in the institution who give evidence of satisfactory progress. An efficient plan of final examination for the granting of general certificates has not hitherto existed in this school, although now about to be introduced; still the students are in great demand by manufacturers, and it is rare to find men who go out with good class certificates waiting any considerable time for employment.

In Prussia there are several other technical institutions for engineers, architects, and commercial men; but a description of them is without the limits of my present Lecture, or at all events, cannot be introduced in the time at my disposal.

SAXONY.

The Secondary schools of Saxony, like those of Prussia, are of three kinds, viz., Gymnasia, Real, and Trade schools. There are nine Gymnasia,* seven of them being supported by the localities, and two by Government. At present there are only four Real schools,† but three others are being founded. The Trade schools are three in number, and are situated at Chemnitz, Plauen, and Zittau; they are chiefly supported by Government, the communes finding the site. The first costs the Government about 1,000*l.* annually; the two latter between 400*l.* and 500*l.* each. Public opinion is still divided as to whether the Gymnasia or Real schools give the best general secondary education, but there is a general agreement as to the advantages of the Trade schools, which are steadily increasing in the number of their pupils. They carry their instruction so far that their pupils may at once pass into the higher division of the—

Polytechnic School of Dresden.

This school is placed in a large and handsome building, and is well organized and conducted, although its annual revenue, amounting to 2,600*l.*, is so much less than that of the Industrial Institute of Berlin. The school is divided into three parts, viz., the Under school, the Tech-

* The Gymnasia are placed as follows: two in Dresden, two in Leipsic, and one in each of the following towns: Freiberg, Zwickau, Bautzen, Meissen, Grima. The two latter are supported by Government, the others being communal.

† There are two Real schools in Dresden, one in Leipsic and one in Anaberg.

nical or Upper school, and the Architectural school. It has been found expedient, as in the Institute at Berlin, to make certain fundamental classes common to all students, and then to divide the instruction into specialities, those of the Technical school being—

- A. Mechanists.
- B. Civil engineers.
- C. Chemists.

The Under part of the school commences generally with students of sixteen years of age, and lasts for three years. The instruction given is as follows; the number of hours devoted weekly to each subject being given:—

LOWEST DIVISION.

CLASS III.					
Winter.	Sum-mer.	—	Winter.	Sum-mer.	—
Hours.	Hours.		Hours.	Hours.	
5	5	Stereometry and trigonometry.	2	2	Laws of projection,
5	5	Algebra.	2	2	Plan drawing.
4	4	Experimental physics.	6	6	Ornamental drawing.
3	3	German.	2	2	Natural history or practical
3	3	French.			geometry.

CLASS II.			CLASS I.		
Winter.	Sum-mer.	—	Winter.	Sum-mer.	—
Hours.	Hours.		Hours.	Hours.	
4	4	Analytical geometry (in the plane).	4	4	Analytical and descriptive geometry.
5	5	Mechanics.	5	5	Mechanics.
4	4	Theoretical chemistry.	5	5	Machinery.
4	4	Mineralogy.	3	3	Mechanical technology.
2	2	Architectural science.	4	4	Technical chemistry.
2	2	Practical geometry (Class III.)	2	2	German and logic.
3	3	German.	2	2	French.
3	3	French.	3	3	English.
6	6	Machine-drawing.	4	4	Machine drawing and perspective.
4	4	Ornamental drawing.			Architectural drawing.
4	2	Field surveying (practical).			
4	2	Plan drawing.			

In addition to these there are for—

Winter.	Sum-mer.	—
Hours.	Hours.	
6	6	A. Modelling in wood, and special hours of instruction in machine drawing.
4	2	B. Field surveying, and continuation of practical geometry,
6	6	C. Larger number of hours in the laboratory.

You have now seen what is considered to be the elementary knowledge requisite for the Upper or Technical division of the school, which the students enter at nineteen years of age, remaining two years. The instruction in this division is now as follows:—

UPPER OR TECHNICAL DIVISION.

CLASS II.			CLASS I.		
Sum- mer.	Winter.	—	Sum- mer.	Winter.	—
Hours.	Hours.		Hours.	Hours.	
5	5	<i>For all Students.</i> Differential and integral calculus.	4	4	Higher (analytical) mechanics.
3	3	Mechanical technology.	4	4	The higher physics.
2	4	Geology.	4	4	Astronomy.
2	2	German and logic.	2	2	National economy.
2	2	English.	2	2	Popular jurisprudence.
2	4	Book-keeping.	2	2	German and logic.
$\frac{1}{2}$ day	—	Geological excursions.	2	2	English.
3	3	<i>Section A.</i> Mill machinery and construction.	3	3	<i>For A.</i> Theory of motive powers.
3	3	Higher geodesy.	9	9	Projects for machines.
9	9	Projects for machines.			
3	3	<i>Section B.</i> Higher geodesy.	3	3	<i>For B.</i> Brick and stone-work (methods and contracts).
4	4	Roads, railways, and hydraulic engineering.	1 day	4 {	Practical surveying.
1 day	4 {	Practical working in surveying.	9	9 {	Plan drawing.
9	9 {	Plan drawing.			Building projects.
	9	Projects for machines and for hydraulic works.			
12	16	<i>Section C.</i> Laboratory practice.	16	16	<i>For C.</i> Laboratory practice.

It will be observed, with some surprise, that the native language, German, forms a part of the instruction, even in the highest class; and the reason given for this appears to be satisfactory. It was found that mere technical instruction was apt to contract too much the views of the students, and that they had little inclination afterwards to subjects of general interest; but now, through the German class, the students are kept interested in history and polite literature, so that they go out from the school not less instructed technologists, but more cultivated men. Instruction in the modern languages, besides its technical importance, is also made subservient to this end. The school possesses collections and workshops on a moderate scale, but no large machine workshop, as in Berlin. In the vacation, the students, with the sanction and aid of the Government, are engaged in practical operations; some being placed on the railways to work locomotives and aid in the general traffic, while others are sent to coal-works, mines, iron furnaces, &c., and, generally, under the charge of the Professors. The number of students at the time of my visit was 220, each of them paying 4*l.* 10*s.* annually, except a small number who were relieved from payment on the ground of poverty; but, in addition to this, there were 27 who devoted their time to drawing and modelling. The number of Professors in the Technical school is 21. (App. B.)

Besides the Technical school, there is, in the same institution, a school of Architecture, possessing 7 professors and 85 students, during the last session. The instruction given was as follows:—

LOWER CLASS.		UPPER CLASS.		REPETITION CLASS.	
Hrs.		Hrs.		Hrs.	
6	Architectural science.	4	Building.	2	Building economy and contract.
5	Arithmetic.	4	Carpentry.	2	Repetition of architecture.
5	Geometry.	6	Statics and mechanics.	6	Statics and mechanics.
3	Industrial physics.	3	German.	2	German.
4	German.	2	Ornamental drawing.	2	Ornamental drawing.
2	Ornamental drawing.	4	Perspective.	2	Perspective.
4	Projects.	6	Architectural drawing.	16	Projects and plans.
6	Architectural drawing.	4	Projects and building plans.		

The "Maturity" examination, which each student must pass before he obtains a certificate, requires very high qualifications on the part of the pupils, and is conducted before a Royal Commissioner, specially appointed for this purpose, and in the presence of numerous persons who are invited to be present.

AUSTRIA.

Austria has but lately established the *Real* system of Secondary instruction, which is, therefore, only in course of development; and, as yet, she has no Trade schools corresponding to those of Prussia and Saxony. On the other hand, she has several provincial Polytechnic colleges, viz., in Pesth, Prague, Gratz, Brun in Moravia, and Lenberg in Galicia; the number of students at these amounting to about 4,000. In all of them the standard of instruction is said to be high; but I have not seen them. I must, therefore, confine myself to the Polytechnic school at Vienna, one of the largest institutions of this kind in Germany, the number of students in the Systematic part of the school being, at the time of my visit, 1,637, the total number in all sections being 3,378. The State gives from 60,000 to 80,000 florins annually for its support, and the school funds amount to about 30,000 more, so that the total revenue may be taken at between 10,000*l.* and 11,000*l.* The education is gratuitous; the only sum charged being a matriculation fee of 8*s.* There are only about 25 exhibitioners, who receive sums varying from 10*l.* to 20*l.*

The organization of this institution is peculiar, and requires a little explanation. It is divided into four sections proper, and one section for popular instruction; these sections are:—

- A. *Technical*, comprising the physical and mathematical sciences, in their industrial application.
- B. *Commercial*, for instruction in all matters involved in the occupation of a merchant.
- C. *Preparatory Division*, for the instruction of those who have entered without sufficient preliminary knowledge.
- D. *Trade Drawing*.
- E. *Popular Section*, for instructing workmen on Sundays and holidays.

As I have only to make a passing allusion to the two last sections, they may be taken first in order. The habits of foreign nations on Sunday have led to the formation of Sunday schools, for secular and not for religious knowledge; and these I found in every large town on the continent. Last year the attendance of workmen at the Sunday school in connexion with the Polytechnic Institution at Vienna was as follows:—

For mathematics	-	-	-	-	-	190
Mechanics	-	-	-	-	-	116
Experimental physics	-	-	-	-	-	211
Chemistry	-	-	-	-	-	133
Drawing	-	-	-	-	-	731

Besides this general instruction on Sunday there are extraordinary lectures in mathematics, German, French, English, Bohemian, Turkish, Italian, and stenography.

In section D. or Trade drawing there are seven professors, and the instruction extends from four to five hours daily. The attendance at the time of my visit was as follows :—

Preparatory drawing	-	-	-	-	184
Manufacturing drawing	-	-	-	-	86
Drawing for metal work	-	-	-	-	76
Machine drawing	-	-	-	-	14

I must, however, pass on to the systematic sections of the institution. The course of instruction generally lasts for five years, the student, being in his sixteenth year before he enters the Technical division, must show evidence of possessing a sufficient amount of elementary knowledge. There is a little want of system in the division of studies, the student being left to choose his own lectures ; although the Director offers to advise him when required. I am, therefore, unable to divide the courses into years ; but the following scheme gives the number of hours devoted in each week to the subjects :

PREPARATORY CLASS.		TECHNICAL SECTION.		COMMERCIAL SECTION.	
Hrs.		Hrs.		Hrs.	
10	Mathematics.	10	Mathematics.	5	Mercantile science.
3	Physics.	10	Differential and integral calculus.	3	Commercial law.
3	Natural history.	5	Descriptive geometry.	4	Style and composition.
5	Style and composition.	10	Drawing.	5	Mathematics and algebra.
10	Drawing.	5	Practical geometry.*	2	Raw materials and products.
		5	Mechanics.	2	Geography, trade, &c.
		7½	Architecture.	5	Book-keeping.
		7½	Engineering.		
		5	Mechanical technology.		
		5	Geology and mineralogy.		
		5	Botany.		
		5	Physics.		
		5	General chemistry.		
		4	Technical chemistry.		
		5	Agriculture.		
		5	Ornamental drawing.		

* This scheme does not, however, give a fair representation of the subjects taught, many being included under one title, as, for example :—

Practical geometry includes	{	Planimetry.
	{	Surveying.
	{	Measuring heights, and levelling.
	{	Plan drawing.
Mechanics include	{	Laws of machinery.
	{	Construction of machines.
	{	Machine drawing.
Architecture includes	{	Architectural Science.
	{	" " Economy.
	{	" " Book-keeping and contracting.
	{	" " Drawing.
Engineering includes	{	Road and Railway engineering.
	{	Hydraulic engineering.
	{	Book-keeping and estimates.
	{	Engineering drawing.
Technical chemistry includes	{	Fermentation.
	{	Soap-making.
	{	Colours, dyeing, calico printing.
	{	Tanning.
	{	Starch, sugar-making, &c.

Drawing in all these cases is taught with a view to the speciality.

The experience of the voluntary choice of lectures has led to the following division, as that which is found best adapted to engineers, although its adoption is not compulsory upon them:—

YEAR I.	YEAR II.	YEAR III.
Mathematics. Technology. Drawing.	Differential and integral calculus. Physics. Descriptive geometry. Geometrical drawing.	Mechanics. Machine drawing. Practical geometry. Plan drawing.
	YEAR IV.	YEAR V.
	Architecture. Chemistry. Mineralogy.	Roads and railways. Hydraulic engineering. Engineering drawing. Book-keeping. Technical chemistry. Mineralogy.

This scheme is given as an example of the division adopted; but it is varied to suit the art for which the pupil studies, and the course is arranged between him and the director. The collections of this institution are ten in number, and well adapted for the purposes of study. (App. C.) The models for these are made by workmen on the premises, but there is no general workshop as in Berlin. The laboratory is well arranged, and consists of several rooms admirably fitted up, a special allowance of 120*l.* being annually made for the purchase of material, &c. The number of professors, teachers, and assistants in the institution amounts to 58, exclusive of the house staff. It will, therefore, be apparent, that the institution is on a large scale, and that the instruction is comprehensive in its character, although not so systematic as in some of the other German schools. The examinations for certificates are not made in the regular or open manner of those to which I have already alluded; but it is understood that new regulations with regard to them are under consideration. Nevertheless, I was assured by Chevalier de Burg, the late director, and Professor Redtenbacher, that, notwithstanding the large number of students, the demand for them by industrial establishments is greater than can be readily supplied.

BAVARIA.

In Bavaria there are no Real schools, and only a few of the Gymnasias introduce realities into their courses; but there are 26 Trade schools, or, in fact, one such school for every large town. I find by the statistics of 21 schools, which I have obtained, and proportioning for the five, of which I have no account, that there are above 3,000 pupils annually obtaining the high education given in these Trade schools. The schools are supported by the Commune, aided, when necessary, by the Province. The management of the schools and appointment of the professors rests with the locality; but the Government exercises a supervision, and sends Com-

missioners annually to examine and report upon them to the Minister of Trade. The courses extend over three years; and as the entrance age is twelve, the pupil at fifteen may pass into the higher Polytechnic Colleges. Of these there are three, one being in Munich, another in Nurnberg, and the third in Augsburg. They are chiefly supported by Government, which allows, however, only 39,000* Bavarian florins, or 3,250*l.*, for their support; and the number of pupils amounts to 481, the professors being 34 in number. In addition to these higher Polytechnic schools, there are two Commercial schools, also supported by Government (at Nurnberg and Furt), and there is a Building school at Munich, which is chiefly intended for the instruction of master masons and carpenters (see Appendix D). Besides these, there are Industrial schools for workmen on Sundays and holidays; and the pupils attending them cannot be less than from 8,000 to 10,000.

The system of industrial instruction in Bavaria dates from 1833, and so satisfied is the Government with its effect that they continue to support and extend it with great liberality. It would be impossible in this Lecture to describe to you the details of the systems of instruction pursued, even in each of the three Head Colleges; and I confine myself to simply giving you the scheme of the Munich institution, referring you to the Appendix for fuller descriptions. I ought, however, to state, that it would require a union of all three Colleges to make really one Polytechnic Institute; as each of them practically, though not professedly, gives a leaning to special branches of the Arts; thus, Munich chiefly devotes itself to civil engineers and architects; Augsburg, to mechanists; and Nurnberg, to chemists; I confine myself, however, to the Institution at Munich, as an illustration. It is situated in a large and commodious building, possesses admirable collections, especially one of physical apparatus, and has a modelling and sculpture workshop in great activity. The number of its professors and teachers is 16, and of pupils 307, of whom 83 are foreigners. Its course of general instruction extends over three years, but engineers take a special fourth year's course. The scheme of instruction is as follows:—

COURSE I.		COURSE II.	
Hours.		Hours.	
7	Mathematics.	7	Analytical mechanics.
7	Physics.	6	Machinery and machine drawing.
7	Machinery and machine drawing.	2	Plan drawing.
2	Plan drawing.	7	Chemistry.
3	Descriptive geometry.	7	Differential and integral calculus.
2	Ornamental drawing.	4	Architecture.
2	Catholic religion.	3	Building materials.
2	Protestant religion.	3	Electro-magnetism and telegraphs.
COURSE III.		ENGINEERING COURSE.	
Hours.		Hours.	
7	Applied mechanics.	12	Roads and bridges (in winter).
4	Geodesy.	12	Hydraulic engineering (in summer).
4	Machinery and machine drawing.	12	Constructions and projections; building; surveying.
6	Analytical chemistry.	8	Architectural drawing and modelling.
6	Applied architecture.		

* Munich receives 18,000 florins, Augsburg 9,000, Nurnberg 12,000; and in addition, they may receive from 800 to 1,200 florins (1 florin = 1*s.* 8*d.*) each from pupils.

Certificates of proficiency are granted, the examinations being made before a Royal Commissioner, who has to report to the Board of Trade on the efficiency of the institution. The architecture of Bavaria, and the excellent engineering which is observed there, is said to be, in a great measure, due to this school; and it is undoubted that its pupils are in great demand, and fill important positions in industry.

GRAND DUCHY OF BADEN.

In the Duchy of Baden the Secondary schools are of three classes, the Gymnasias, the High *Bürger*, and the Trade schools, but the latter do not possess the same high standard of instruction as in other places; and the students of the *Bürger* schools act as feeders to the Great Polytechnic Institution, while the Trade schools are chiefly devoted to the education of workmen. The Polytechnic school of Carlsruhe is perhaps the most efficient one in Germany; and as its constitution and organization are probably more nearly allied to any similar institution that might arise in this country, I will enter into its description somewhat in detail. The school is now about 18 years old; but its present state and organization have resulted from the experience of the last ten years. It has two main divisions, viz.:—

- A. Preparatory section, consisting of three mathematical classes.
- B. The *Fach* schools, or schools of specialities, consisting of—
 - a. Engineering.
 - b. Architecture.
 - c. Forestry.
 - d. Chemistry and technology.
 - e. Mechanical technology.
 - f. Commerce.
 - g. Post-office.

The Polytechnic school is under the Minister of the Interior, and is managed by a director, annually elected by the professors from among themselves, and by another self-elective machinery, which appears to be unnecessarily complicated.

- a. A special council of teachers, consisting chiefly of the principals of the Special schools.
- b. A general council of all the teachers.
- c. An executive council.
- d. An auditor.
- e. A secretary.

Although there are seven Special schools, several of the professors teach in more than one; but dividing them into their respective sciences, we find the following large staff of teachers:—

Mathematics	-	-	-	7	Drawing	-	-	-	2
Natural and physical sciences	-	-	-	5	Ornamental writing	-	-	-	1
Architecture	-	-	-	6	Modelling, carpentry, and machine	}	-	-	3
Engineering	-	-	-	2	working				
Forestry	-	-	-	3	General subjects	-	-	-	10
Sculpture	-	-	-	2					

Thus there is a staff of 41 teachers to about 330 students, of whom 112 are foreigners.* This institution differs from most schools in Germany by being to a great extent self-supporting, the Government grant being only 32,000 florins, while the expenses are above 50,000 florins. It does, indeed, seem extraordinary that with a revenue of little more than 4,000*l.* (4,166*l.*), this institution is able to accomplish as much as it does. The cost to each student is about 6*l.* annually. The periods of the courses vary according to the speciality to be studied, as will be seen by the schemes of instruction.

Mathematical or Preparatory Course.

(Course, 3 years.)

CLASS I.		CLASS II.		CLASS III.	
Hrs.		Hrs.		Hrs.	
1	Catholic religion.	2	Catholic religion } with	4	Descriptive geometry.
1	Protestant religion.	2	Protestant religion } Class I.	3	Analytic geometry.
6	Arithmetic and algebra.	4	Analysis and higher equations.	5	Integral and differential calculus.
4	Geometry.	2	Plane and spherical trigonometry.	5	Elements of mechanics.
8	Introduction to descriptive geometry.	2	Analytical geometry.	4	Practical geometry.
2	German.	8	Descriptive geometry.	6	General chemistry.
6	French.	5	Statics.	4	Mineralogy and geology.
4	General history.	4	Physics.	3	French (third course).
4	Drawing.	2	German (second course).	3	English.
1	Writing (ornamental).	3	French (second course).	4	Drawing.
		2	Drawing.	-	Modelling.
		4	Modelling.		

Special Schools.

A. Engineering school.

(Course, 3 years.)

COURSE I.		COURSE II.		COURSE III.	
Hrs.		Hrs.		Hrs.	
3	Higher analysis (in winter)	12	Civil engineering (higher)	12	Projects and contracts.
3	Higher mechanics (in winter)	10-12	Machinery.	4	Higher architecture.
8	Civil engineering.	2	Jurisprudence (summer).	3	Higher geodesy.
12	Machinery.	4	Plan drawing.	2½	Practical surveying.
4-6	Practical architecture (drawing and modelling).				
3	Ethics.				
4	Plan drawing.				
3	English.				

B. Architectural school.

(Course, 4 years.)

COURSE I.		COURSE II.	
Hours.		Hours.	
4	Spherical trigonometry and analytical geometry.	4	Technical chemistry.
4	Differential and integral calculus (first course).	3	Ethics (in winter).
5	Elementary mechanics and hydraulics.	4	Figure drawing.
2	Literature and style.	5	Drawing.
4	Descriptive geometry (second course).	8	Modelling.
5	Drawing.	5	Ornamental drawing.
8	Modelling and workshop.	7	Projects and contracts.
5	Ornamental drawing.	3	Technical architecture, architectural statics.

* Of these 112 there were 72 Germans from other States, and 40 "*Ausländer*," consisting of English, French, Swiss, Dutch, Belgians, Hungarians, Poles, and one East Indian.

COURSE III.		COURSE IV.	
Hours.		Hours.	
6	Roads and hydraulic engineering.	4	Mineralogy and geology.
6	Practical construction of the above.	2	Jurisprudence.
6	Laws of machinery.	4	Modelling and ornamenting.
3	Esthetics.	5	Shadowing and plaster casting.
4	Architecture.	3	Monumental architecture.
5	Ornamental drawing.	5	Plans and contracts for great buildings.
4	Modelling.	5	Painting and perspective.
5	Projects for dwelling-houses.	3	Archæology.
3	Higher architecture.		

C. *School for Forestry.*

(Course, 2 or 3 years.)

PREPARATORY CLASS.		COURSE I.		COURSE II.	
Hrs.		Hrs.		Hrs.	
4	Mathematics.	4	Practice in "forest mathematics."	3	Agricultural chemistry.
4	Physics.	4	Technical chemistry.	2	National economy.
4	Botany.	3	Mineralogy and geology.	3	Preservation of forests.
4	Zoology.	4	Botany.	2	Forest statics.
2	German.	3	Meteorology; soils.	7	Forest economy.
		3	Forest trees (Botany of).	2	Forest laws.
		6	Forests.	3	Forest police.
		4	Forest economy.	2	Forest rights and sports.
		2	Wood taxation.	-	Excursions.
		2	Road-making.		
		4	Practical geometry.		
		-	Scientific excursions in the woods.		

D. *Chemical school.*

(Course, 2 years.)

COURSE I.		COURSE II.	
Hours.		Hours.	
6	General chemistry (in winter).	4	Special technical chemistry.
4	Technical chemistry.	3	Analytical chemistry.
7	Botany and zoology.	3	Special subjects in chemistry.
4	Mineralogy and geology.	4	Mineralogy and geology.
4	Practical geometry.	2	Popular engineering.
4	Popular mechanics.	3	Ethics (in winter).
2	Mechanics applied to transport.	-	Working in laboratory.
4	History.	-	Languages.
6	Book-keeping and commercial law.		
-	French, English, drawing, workshops.		
-	Chemical laboratory.		

E. *Mechanical school.*

(Course, 2 years.)

COURSE I.		COURSE II.	
Hours.		Hours.	
6	Construction of machines.	6	Machinery and technical mechanics.
6	Machinery (Laws of).	6	Construction of machines.
6	Workshop.	6	Mechanical workshop.
4	Physics.	4	Technical chemistry.
3	Higher analysis (second course).	4	Engineering (second course).
3	Higher mechanics (in winter).	6	English.
4	Engineering.		
-	French.		

F. *Commercial school.*

(Course, 1 year.)

Hours.	—	Hours.	—
4	Commercial law.	1	History of commerce.
2	Book-keeping.	2	German.
2	Correspondence.	4	French.
3	Commercial arithmetic.	3	English.
2	Products (Knowledge of).	2	Calligraphy.
2	Commercial geography.	2	Drawing.

Postal school.

(Course, 2 years.)

COURSE I.		COURSE II.	
Hours.	—	Hours.	—
3	Arithmetic.	2	Political arithmetic.
2	Geography.	2	Geography.
4	Mechanics (Popular).	2	National economy.
4	Physics.	2	Jurisprudence.
4	General history.	3	Commercial contracts.
2	Religion.	2	Mechanics applied to transport.
4	French and French commerce.	4	German and Composition.
2	German.	5	French.
2	Calligraphy.	3	English.
		2	Calligraphy.
		3	Ethics and Æsthetics.

You will observe, however, that this institution differs from all those which we have already examined by splitting its instruction into seven different specialities, and that therefore it deserves the name of a Polytechnic Institution more than the others. The mode of instruction in all the schools is by lectures, practical working in the laboratory, the carpentry and machine shops, and in surveying; while at the same time examinations and repetitions are very frequent. The formal certificates of the Special Technical schools are said to be in the highest estimation, and command immediate employment to the possessors.

EXTENT OF THE INSTRUCTION IN GERMANY.

I have now concluded the description of the Industrial schools of Germany, so far as my personal knowledge extends. There is, however, an excellent Polytechnic Institution in Hanover which I have not had time to visit, and therefore regret that I am obliged to omit its description. Reviewing what has been said, and adding a fair proportion for the districts not visited, it is quite certain that at least 13,000 well qualified students *

* This is exclusive of the workmen in the Industrial Sunday schools. The number of pupils at these cannot be under from 30,000 to 40,000; although I give this number only as an approximative estimate made from the proportion of systematic pupils to Sunday pupils in the schools from which I have obtained the statistics. For a popular explanation of these schools, and their general effect upon industry, I would refer to Zschokke's excellent little volume, "Labour stands on Golden Feet."—Groombridge and Co., London.

are being every year systematically instructed in the industrial institutions of Germany; and when you consider the character of that systematic instruction, if you agree in the general argument with which the Lecture commenced, you will be convinced, that the time has come when England must begin to raise an intellectual force to do battle with that mighty one which is rising everywhere around her. But I must now pass to France, our worthy rival in industry.

FRANCE.

It is well known that France encourages to a great extent the industrial instruction of its producers. The *Ecole Polytechnique* of Paris, the *Ecole des Ponts et Chaussées*, and the *Ecole des Mines*, have been too often described to require more than a passing reference to them. But as they are chiefly for the instruction of Government *employés* they do not necessarily act immediately on private production. At the same time it is not to be forgotten that it is the principle of the French Government to act upon its own perception of right by instructing the population, even before formal demands have been made, on the part of the public, for the benefit which is thus conferred. It is therefore the more surprising, that the middle classes for some time urged their want of an institution for the industrial instruction of their producers, without carrying conviction of its necessity to the Government. Impelled by the urgency of the want, a private institution was raised; and the feeling in its favour was sufficiently strong to induce a capitalist to embark a large sum of money in founding it. This private institution, raised in a capital where the public schools are altogether under the Government, proved that it was a necessity of the times by its immediate and eminent success. Thus rose the *Ecole Centrale des Arts et Manufactures*, now the most important industrial institution in France. It possesses the most eminent men of France as its professors, and it has reared those who promise to be her future brightest ornaments. As a commercial speculation it has been singularly successful, and it still remains under the business direction of the original enterprising capitalist, M. Lavallée. The Government now gives to it a certain number of exhibitions to educate poor students of extraordinary talents, and the Councils General of twenty-nine departments of France also do the same. The appreciation of its importance to France may best be seen in the Report of the Commission of the Chamber of Deputies appointed to inquire into the budget:—

“ You know, gentlemen, this useful establishment, founded in 1829, by the association of eminent professors, with the intention of forming civil engineers, the directors of works, the chiefs of workshops and factories. This private institution, which by its importance rivals in excellence our first public establishments, has created and put in practice a complete system of industrial education. It is at the same time a supplement to our Polytechnic School, and an addition to our various applied schools. Such an institution ministers to one of the first necessities of the age, therefore

its success is complete. This is confirmed both by the unanimous opinion of the first manufacturers of the country and by the ease with which all the pupils educated at it have received employment."

The school possesses 40 professors and teachers, and 300 students, each of whom pay 36*l.* annually. The number of the latter is only limited by the size of the building, and it is in contemplation to remove to one considerably larger. The courses extend over three years, and are compulsory on all, but in the second year the practical operations divide into two parts, the one general and the other applicable to one of the four following specialities:—

- A. Mechanists.
- B. Engineers.
- C. Metallurgists.
- D. Chemists.

Students are not admitted until they are eighteen years of age, and they must furnish proof of possessing a good elementary knowledge of the sciences (App. E). The courses of instruction are as follows:—

YEAR I.	YEAR II.	YEAR III.
Descriptive geometry. Analytical geometry and mechanics. Transformations of motion. Physics (general). Chemistry (general). Chemical manipulation. Hygiene and natural history applied to the arts. Drawing.	Descriptive geometry. Industrial physics. Mechanics. Materials used in construction of machines. Analytical chemistry. Industrial mineral chemistry. Public works. Geology. Manufacture of iron and steel. Technology (cordage, textile materials, cutting wood, stone, &c.).	Steam engines. Railways. Hydrostatics. Construction of machines. Chemical preparations and organic analysis. Industrial organic chemistry and agriculture. Architecture. Mining. Furnaces and foundries. Technology (mills; oil-making; spinning; felting; milling; potteries, &c.).

It will be seen by the above scheme, that after the first two headings in the second and third years, the subjects are parts of corresponding courses, and in practice they are professed every alternate year to the second and third years' students combined. The greatest attention is paid to drawing and design, much time being devoted to them. The students have to make plans to prove their progress; as, for example, a beet-root sugar factory being wanted, the student, from his knowledge of the conditions of the manufacture, must draw out a plan of works, giving estimates, &c. of its cost. Certificates of proficiency are granted after the most severe public examinations extending over many days. I was fortunate enough to be present while these were proceeding, and admired the extent and accuracy of the information possessed by the pupils. But you will ask for the proof of the efficiency of this kind of education for manufacturers; and I reply by stating, that a certificate from this institution is equivalent to assured success in life. Its pupils invariably pass into the most important positions in industry, and not only France, but Spain, Belgium, and England have learned to value them, as we see by the ready manner in which the manufacturers of these countries secure their services. Allow me to give you a few statistics of about 550 of the certificated students, whose occupations are so important that their histories can be traced.

Of this number the following division may be made, all of the occupations being high and responsible :—

Agriculture - - -	18	Chemical arts - - -	57
Architecture, canals, &c. - -	39	Civil engineering, &c. - -	56
Railroads - - -	119	Machinery - - -	30
Professors and teachers - -	42	Metallurgy and mining - -	79
Textile manufacturers - -	36	Paper, commerce, salt-works - -	22
Public works - - -	53		

But the question of its utility may be put in another way : if foreign countries find the pupils of this institution useful, do they send over their own sons for instruction ? To this I reply, that more than 600 foreigners have been educated at this school, and, in analysing its books for statistics to this effect, I was surprised to find, in addition to representatives of the known industrial countries of Europe, numerous students both from North and South America, from Turkey, the Antilles, Hayti, the Mauritius, Madras, Ceylon, Gibraltar, &c. Spain and Belgium send over regularly considerable numbers to this school, and England this year has five or six of her subjects who were obliged to go abroad for that comprehensive instruction which they could not get at home. Experience has shown that it is precisely those countries which do not possess a system of industrial instruction that send the largest proportion of foreigners to be educated there.

Besides this institution which is devoted to the industrial instruction of the middle classes, you all know of that princely establishment the *Conservatoire des Arts et Métiers*, the object of which is, both by its splendid museums and by the lectures of the eminent men who profess there,—and of whom it is only necessary to mention the names of Morin, Dupin, Pouillet, Péligot, Moll, Blanqui, Wolowski, Regnault, and Payen,—to instruct the working classes in industrial science, and to draw public attention to all new discoveries in industry.

This institution is, however, so well known by its beautiful and instructive collections, that I am spared the necessity of describing them.

Under Colonel Morin, the distinguished director who has introduced such life and activity into the *Conservatoire* during the last few years, there are three provincial industrial colleges, each supported by Government at an expense of 300,000 francs, or 12,000*l*. These colleges are situated at Chalons, Angers, and Aix, and contain between 200 and 300 students each, who are boarded and educated at the public expense. The students being of a lower class than those who go to the *Ecole Centrale* and educated chiefly as men who may aspire to be master workmen. Accordingly, five hours every day are devoted to study, and seven hours to the work-shops. Many of the pupils of these institutions obtain Government employment, and those who have passed their examinations find ready occupations as foremen, draughtsmen, and clerks of works. I have not personally seen these provincial schools, but Colonel Morin, the present director, has assured me of their high state of efficiency.

BELGIUM.

In a lecture on Continental industrial instruction it would be wrong to omit allusion to this important producing nation, though I have not recently visited its institutions. The Belgian Government, however, accepting the lesson of the Exhibition, and being convinced of the necessity of industrial instruction to its producers, has recently sent Commissioners to various countries for the purpose of inquiring into this subject, and with the view of immediately establishing a college at Antwerp, and perhaps also at Brussels. Only a few months since M. de Cocquiel made an educational tour in this country, on behalf of the Government; and he could not conceal his astonishment at the character of the instruction with which we had contented ourselves in this country of production. Belgium, however, though it has depended hitherto to a great extent upon the educational resources of the *Ecole Centrale* of Paris, nearly 100 of its manufacturers having been educated there, has not at the same time been altogether negligent in this direction. The University of Liège has special schools of mines, and of arts and manufactures, which have been in operation since 1838. The pupils are admitted to them only after a strict examination in proof of their having the necessary elementary knowledge. The following requirements for the examination of the pupils in each year will also indicate the course of study:—

A. SECTION OF MINES.

YEAR I.	YEAR II.	YEAR III.
Applied mechanics. Industrial physics. Mineralogy. Mineral analysis. Assaying. Drawing, applied to machinery, &c.	Geology. Mining (1st Part). Inorganic technical chemistry. Metallurgy (1st Part). Drawing, applied to geology and mining.	Mining (2d Part). Plan drawing. Industrial architecture. Metallurgy (2d Part). Drawing, applied to the previous subjects. Industrial economy. Mining legislation. English. German.

B. SECTION OF ARTS AND MANUFACTURES.

a. Arts and Manufactures.

YEAR I.	YEAR II.	YEAR III.	YEAR IV.
Statics and dynamics. Elementary physics. General chemistry and manipulation. Descriptive geometry. Drawing.	Applied mechanics. Industrial physics. Mineralogy. Mineral analysis. Assaying. Drawing applied.	Geology. Mining (1.) Chemistry. Metallurgy (1). Drawing applied to preceding subjects.	Mining (2). Plan drawing. Metallurgy. Industrial architecture. Industrial economy. Practice in making plans and contracts. Drawing.

b. Mechanics.

YEAR I.	YEAR II.	YEAR III.
Statics and dynamics. Elementary physics. Inorganic chemistry. Descriptive geometry. Practical drawing and shading. Workshop practice. Design.	Applied mechanics. Machinery drawing and shading. Industrial physics. Workshops.	Industrial architecture. Construction of machines. Projects for machines. Workshops. Machinery drawing.

In addition to these courses, there are others by *Répétiteurs* on design, topography, and surveying, differential and integral calculus, analytical mechanics, &c.

It is therefore obvious that Belgium cannot be classed as a country which has neglected the industrial instruction of its producers, although it is now about to give it a fuller and more efficient development.

I have now only a few words to say with regard to other countries, because, with the exception of Denmark, I have no personal knowledge of their industrial institutions. In Madrid there is an institution and museum similar to the Conservatoire des Arts et Métiers, but for the systematic instruction of the middle class of producers the *Ecole Centrale* of Paris is still used by Spaniards.

With regard to Scandinavia it will not be necessary to detain you long. It is well known that there is an excellent institution in Stockholm which has exercised the most material influence on Swedish industry; but though anxious to inspect it this year, I found that the time at my disposal would not permit me to do so. In Denmark the secondary education is tending much to the Real system, notwithstanding the present excellent combination of classical learning with *realities* in the Gymnasia. The Polytechnic Institution of Copenhagen was founded in 1829, and is chiefly supported by Government, which gives 12,000 rixdollars annually, while the fees of the students amount to about 2,000 more. The total revenue of the institution does not therefore reach 1,600*l*. The number of students is not great, there being at present only 44 matriculated "polytechnics," and about 60 other students attending special lectures, while there are 9 professors.

The course of instruction divides itself into three specialities;

- A. Mechanical section.
- B. Scientific section.
- C. Agricultural section.

The courses of instruction for each of these divisions are seen in the following schemes:

A. Mechanical Section.

YEAR I.			YEAR II.		
Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
5	4	Mechanical physics.	9	9	Mathematics.
5	—	Chemical physics.	2	—	Descriptive geometry.
5	—	General chemistry.	6	6	Mechanical technology.
7	8	Mathematics.	5	—	Industrial physics.
4	4	Descriptive geometry.	5	—	Technical inorganic chemistry.
—	4	Optics.	—	4	Machinery.
9	—	Geometrical drawing.	9	—	Machine drawing.
—	6	Machine drawing.	—	12	Projects for machines.
—	12	Laboratory practice.			

YEAR III.		
Winter.	Summer.	—
Hours.	Hours.	
8	—	Machinery.
9	—	Mechanical technology.
12	18	Construction of machines and workshops.

B. Scientific Section.

YEAR I.			YEAR II.		
Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
4	4	Mathematics.	4	4	Mathematics.
5	—	Mechanical physics.	—	6	Mechanical technology.
5	—	Chemical physics.	—	4	Machinery.
5	—	General chemistry.	5	—	Industrial physics.
—	5	Organic chemistry.	2	—	Geology.
—	5	Chemical analysis.	4	—	Zoology.
—	4	Optics.	5	—	Technical organic chemistry.
2	—	Crystallography.	—	4	Botany.
—	2	Geognosy.	12	12	Laboratory work.
—	12	Laboratory work.	6	6	Drawing of apparatus.
—	6	Drawing of apparatus.			
9	—	Geometrical drawing.			

YEAR III.		
Winter.	Summer.	—
Hours.	Hours.	
6	—	Technical organic chemistry.
9	—	Mechanical technology.
12	whole time.	Laboratory work, drawing, &c.

C. Agricultural Section.

YEAR I.			YEAR II.			WINTER III.	
Winter.	Summer.	—	Winter.	Summer.	—	Winter.	—
Hrs.	Hrs.		Hrs.	Hrs.		Hrs.	
5	—	Mechanical physics.	5	—	Industrial physics.	5	Technical organic chemistry.
5	—	Chemical physics.	4	—	Zoology.	—	Laboratory.
5	—	General chemistry.	—	4	Botany.	6	Drawing.
—	5	Inorganic analysis.	5	—	Technical chemistry.		
—	12	Laboratory.	12	12	Laboratory.		
6	6	Drawing.	6	6	Drawing.		
—	3	Agricultural chemistry.	4	—	General agriculture.		
3	—	Agricultural implements.	—	5	Breeding of cattle.		
			—	3	Systems of agriculture.		

The Polytechnic Institution of Copenhagen, as will be seen from the above scheme, has an extended system of instruction; but, nevertheless, it has not been very successful in its operations. One reason assigned for this is, that its instruction is too abstract, and neither special enough, nor sufficiently technological; but the other and perhaps true cause is, that Denmark is not yet a large manufacturing country, and that in absence of all fuel except wood and peat, and of the main raw materials used in production, its manufactures are only likely to be of slow growth. Accordingly there are not sufficient outlets in Danish industry for a large number of pupils of such a school, and accordingly I find that only 66 men have taken diplomas between 1829-1848, of whom 25 are in Government employment, 23 in manufactures and workshops, and the remainder as teachers in Real schools, &c.

Since 1848 about 24 more pupils have passed, and are well employed. In fact, the present natural outlet for such an institution in Denmark is in civil engineering, and to this many persons think it should be mainly

directed. At the present moment extensive changes in its organization and objects are in contemplation, although unfortunately the idea of converting it into a military school seems to be the prominent one.

I would refer to the Appendix (F.) for the account of a most interesting institution, named "The Technical Institute of Copenhagen," which is chiefly devoted to the instruction of workmen, of whom 520 were in regular attendance last session. The institution is, in fact, a school of design, but is remarkable for the detailed applications of art, there being a class for almost every trade; as, for example, for brick-builders, carpenters, cabinet-makers, tin-plate-workers, lock-makers, gas-fitters, goldsmiths, bookbinders, carpet-makers, &c. But besides design, mathematics, physics, the nature of building materials, and other subjects of a like nature, are taught. This institution is supported by private subscriptions, and the expenditure does not amount to 400*l.* annually.

Before concluding, it may be useful to draw attention to some general points of interest in the systems of instruction which we have examined. In all of them there are differences with regard to the mode of giving instruction, but they are almost uniform in the feeling that the object of Industrial schools is only to teach a pupil how to become an intelligent manufacturer, without attempting to make him one. They content themselves with communicating to him a knowledge of the principles upon which his technical art depends; but for its practice he must go to the workshops of industry. Some of the institutions, as, for example, the Trade Institute of Berlin, endeavoured at one time to teach practice in workshops attached to the institution, but this plan, as might have been anticipated, was found to be of little advantage, and it is now abandoned by almost all the schools, only one or two being still found hovering on the outskirts of this error. In addition to the folly of attempting to teach the practice of an art within the confines of an institution chiefly devoted to other objects, it was found to be highly detrimental to the progress of the students, who were glad to escape from the mental labour of the classes to the muscular labour of the workshops.

This is the point upon which the producer and the promoter of industrial instruction are likely to disagree, unless they thoroughly understand each other; and I am therefore anxious that there should be no mistake on this subject. We do not think that in such schools we can furnish a substitute for the practical training of the workshop, the factory, or the office of engineer; but we do think, that a producer possessing a knowledge of natural forces will become a practical man in a shorter time than without it, and that he will know how to turn his practice to the best account. Let me instance the case of a surgeon, as an illustration. For a long time surgery was only an empirical art, carried on by monks and Jews, until the Council of Tours, in 1163, prohibited the former from operating, and then it fell into the hands of barbers and smiths. No one doubts that much useful experience was acquired by them; and their empirical experience assumed the character of a system at a time when Edward IV. allowed no one but barbers to practise

in London. It was not till the eighteenth year of George II. that barbers and surgeons were finally separated from each other, and that the latter were allowed to fix the standard of their own qualifications. All the fears expressed by manufacturers now were expressed by the barbers on the eve of their separation from the surgeons, and so alarmed were the former for the safety of the public in the hands of the latter, that they got a provision introduced in the deed of separation by which surgeons are strictly prohibited from exercising "the feat or craft of barbery and shaving." But does history tell us of any dread evils which arose from giving surgeons more of a scientific and less of a rule of thumb education? No one ever dreamt of turning out a young man from a lecture-room as a ready-made surgeon; he must have had hospital practice before he is launched into his profession, and much general practice before his course in life is assured. But it is not now pretended by any one that his education in science renders him less fit to avail himself of the experience of this practice; on the contrary, it is admitted that it is essential for him, and that he benefits more by the practice than he would have done had he not had the science. The quack or the empiric depends upon experience alone, and often works real cures, but he fails as often, because he is ignorant of the cause of his success, and an application of the same practice under other conditions may produce fatal results. "Science renders the powers of nature the servants of man, whilst empiricism subjects man to their service. The empiric, placing himself on a level with an inferior or unconscious being, employs but a small portion of his power for the advantage of society. He permits effects to govern his will, whilst, by a true insight into their hidden causes, he might govern them."—(Liebig.)

One other illustration will suffice. In the most critical time of the Peninsular war, the Duke of Wellington found himself deficient in the number of military engineers, and commissions were freely given to Cambridge mathematicians. The wise Commander knew that men possessed of the necessary scientific knowledge could be trained to practise more quickly than those who had it not. He did not dream of giving to a mathematical theorist the charge of the works at Badajoz or Almeida, but he felt that experience would more quickly flow into a mind fitted to receive it than into one which had not been thus prepared.

The promoters of industrial instruction do not, therefore, offer it as a substitute for practical training, but consider it to be a means by which the latter can be made more efficacious. They do not think that the seed will grow, unless the land is well tilled by the practical farmer, but they offer to manure the land first, and the ploughing-in the manure will enrich the soil and render it more productive.

Another point, common to the higher industrial institutions abroad, is, that they do not communicate elementary knowledge in science, but only teach its applications to industry. They originally experienced the same evil that we have at present in this school (Government school of Mines, &c.), that the pupils came untrained in science, and that the time was spent in teaching its elements, instead of its applications. But gradually raising their standard of knowledge for admission, the public perceived what was

required of them, and came with sufficient preliminary acquirements. Some idea may be formed of the state of education by the fact, that pupils are not generally admitted into the Upper Technical class of mechanics, physics, and machinery, unless they have passed examinations in integral and differential calculus. This condition for admission has a twofold advantage; first, that it enables professors to devote all their time to the industrial applications of science; and then, that the Industrial institutions, instead of acting as antagonists to those for general education, actually give them the greatest impulse, and are their most powerful supporters.

We must also observe the favourable results which arise from the close connexion of the sciences and of art in the same institution. Mathematical science is not studied and kept apart as a separate branch of knowledge, as is too frequently done in some of our most important schools and colleges, but she is used as the handmaid and interpreter of all the other sciences, and even of art; and it is with this view that so much time is devoted to her study. Perhaps Aristotle was too limited in his views when he said, "Physics and mathematics make practice;" but Bacon was certainly not in error when he wrote, "For as physical knowledge daily grows up, and new actions of nature are disclosed, there will be a necessity for new mathematical inventions." And what a commentary on this text is our present knowledge in astronomy, navigation, logarithms, surveying, the theory of tides, the wave theory of light, the attraction of spheroids, and of the mass of the earth! In all the courses of the institution, even in architectural and machinery drawing, mathematics give powerful aid. Drawing, in the same way, is used throughout the courses as a handmaid to every science and art, and is not kept in an isolated position, as in our Schools of Design. Hitherto the practice in them has been to teach students to draw, though it is difficult to know how they could be taught to design for arts, regarding which they have had no instruction either as to their wants or their resources.* Abroad, the Schools of Design form part of the Schools of Industry. In our country we are doing much in a fragmentary and dispersed way, which a little union and system would make far more important to industry than it is now.

The comprehensive system of instruction pursued abroad is found to have a most happy effect on the future career of the student. The manufacturing chemist leaves the school with a sufficient knowledge of the principles of machinery to guide him in its management, or to aid him in the expression of his requirements. He can plan and sketch the buildings, machinery, and apparatus which he may require, and he has been taught enough of building and contract work to know whether the plan of the architect is sufficient, and the charges of the builders within moderation. The architect does not end his education with drawing elevations and planning interiors; but chemistry and physics have shown him how to test the qualities of his building materials, and have taught him the principles

* Mr. Cole, the present enlightened Superintendent of the Department of Practical Art, has begun to remedy this defect, as far as regards the Central School.

of ventilation, lighting, acoustics, and drainage, while mathematics enable him to calculate the stability of his structures. These illustrations are sufficient, because the schemes of instruction indicate the knowledge which it has been found advantageous to communicate to the producer in each art.

The mere fact that industrial schools are increasing abroad, and that the number of their pupils is constantly augmenting, is of itself a sufficient proof of their influence on industry, even had we no proofs more direct than these. But it is, indeed, extraordinary that the proofs are already so palpable; for it might have been expected that, at least, the time of one generation would have been required to develop their effects. The interests of a nation extend much beyond the interests of the one generation which forms its present population, and the statesman will feel sure that the effects already in action will operate with a much increasing power in the future. The sun of knowledge does not expend its light and heat-giving rays in vain. You do not measure the snows on the hills by the little streams which trickle from their summits; but, taking timely warning from them, you are glad to escape the terrors of the thundering avalanche. I do earnestly desire to convince you of the necessity for immediate action; for delay, until the urgency is more palpable, may be ruinous; we see a stream flowing from the fountain-head of knowledge, and though we pause on the brink, and gaze, it is not likely to run out, but will continually increase in power—

“ Sapere aude,
Incipe. Vivendi recte qui prorogat horam,
Rusticus expectat dum defluat amnis: at ille
Labitur, et labetur in omne volubilis ævum.”

You will perhaps think, that in combating some of the ordinary objections to a system of industrial instruction, I have raised up phantoms only for the pleasure of laying them; and you would be right in this supposition, were it not that the question has been frequently, but no doubt unintentionally, misrepresented and misunderstood. After all, the question resolves itself into a consideration of extreme simplicity, viz., Whether it be wiser to employ natural forces in production, with a knowledge on the part of the producers of what they are, or with a total ignorance of their nature? or, in other words,—Whether it be better to solicit nature to help us, in language intelligible to her, and to which she never refuses to reply, or to assault her with a rude empirical jargon which grates upon her ears, and causes her to turn from us? There is no escape from the simplicity of the position, or from the palpable fact, that continental nations are proceeding in the first conditions of the question, and our country in the second. We cannot blink the fact, that the paths of competition are becoming narrower and steeper, and that foreign nations are learning how to walk in them with open eyes, while we are still trusting to the old expedient of experimentally grappling at objects to pull us up, trusting that, if one support fail, we may catch hold of another before we fall. Who is likely to gain in this game? Let the proverb answer: “A wise man’s eyes are in his head, but the fool walketh in darkness.”

To all this style of reasoning there is but one reply, viz., that England, relying on her experience only, is still in advance in the race of competition.* So she is, on the whole; but is she as much in advance in the quality (not the quantity) of her products, as she was twenty, nay even ten years since? On the contrary, do we not know positively that other nations are closing fast upon her by taking shorter cuts? It is true that we find them sometimes halting in the race; but never mind that—"A cripple in the right way may beat a racer in the wrong."

Let us deal, however, in sober facts, and not in metaphors, and see in what language they speak to us. Is there any significance in the fact that we chiefly relied on the invention and science of a foreigner to tell us the duty performed by the different machines in the Exhibition? What conclusion are we to draw from the following remarks in the official report of the jury on machines? "In reporting upon the hydraulic machines exhibited, it is impossible to refrain from advertent to the general neglect of those elementary principles of scientific knowledge on which the perfection of such machines always depends, and, in some cases, the whole usefulness in an economical point of view. The Exhibition affords positive evidence of the sacrifice of a large amount of capital, and of much mechanical ingenuity, due simply to the ignorance of certain acknowledged principles of hydraulic science. In advertent to this fact, the jury cannot but observe that the success with which the principles of mechanical science in their application to practical questions are beginning to be cultivated in France appears in the superiority of the French hydraulic machines. It is but reasonable to expect that the superiority which the French have attained in certain branches of industry, by their attention to the art of design, will eventually appear, through the agency of the *Ecole des Arts et Métiers*, in the scientific character of their machines." A striking fact, illustrating the inefficiency of mere experience, was shown by the trials in the Exhibition; for, notwithstanding the great antiquity of water pumps, and the experience which England has had in them, it was found, on subjecting the most approved forms to trial, that from 55 to 80 per cent. of their effective power is actually *lost*; a fact which experience did not suspect, but which science has proved, and at the same time indicated its remedy.

In the report on glass we find the jury saying, "We see, and see it with satisfaction, that the foreigners are making rapid advances, and are bringing their intelligence and their taste into competition with us . . . it becomes our duty as well as our interest not to be backward in the struggle . . . On behalf of that art, therefore, which is under our consideration, we claim the exercise of increased energy and science." Even with regard to our cutlery, we are told by the jury "that it would be untrue and unfair" not to state "that we have in certain branches of the manufacture some formidable rivals." Still more surprised were we, in hardware, to

* We are apt to be led into the question of competition, with which the argument has, in reality, little to do. If it be true, that a knowledge of natural forces aids production, then is it of advantage to the producer to acquire that knowledge; and this would be the case, even if there were no industrial competition in the world.

find "Austria, the States of the Zollverein, and Belgium, affording ample proofs of activity; the first-named country, in particular, exhibiting remarkable productive vigour." But why tire you with more quotations, when your every-day experience shows the increasing vigour of foreign industrial competition? When, therefore, we see competition thus pressing upon us on all sides, is it a sufficient reply to my argument to say, that because on the whole England is yet in advance, she is not to increase her rate of progress? or is it wise to go on nursing ourselves in national vanity, and in our isolation refuse to look at the causes which produce the rapid strides of industrial progress in other parts of the world? What these causes are I have endeavoured to explain, and the nature of the evidence has been laid before you. I do not doubt that you will properly appreciate its value; and if you arrive at the same conclusions as myself, you must be satisfied that it would be unwise further to delay the instruction of our industrial population, and will not, therefore, be surprised that I conclude with a warning quotation from Martial*:

"Old Priam's age or Nestor's may be out,
And thou, O *Taurus*, still go on in doubt;
Come, then; how long such wavering shall we see?
Thou may'st doubt on; but then thou'lt nothing be."

* F. Lewis' translation of—

.
Et non decernis *Taure*, quid esse velis,
Peleos et *Priami* transit, vel *Nestoris* ætas,
Et serum fuerat jam tibi desinere.—
Eja, age, rumpe moras, quo te spectabimus usque?
Dum quid sis dubitas, potes esse nihil.—*Mart.*

APPENDIX A.

TRADE INSTITUTE OF BERLIN.*

THIS institution, as stated in the Lecture, has undergone various modifications in its constitution, and it may be desirable briefly to refer to them. It was founded in 1821, chiefly at the instigation of Von Beuth, who remained Director of it, and the Trade schools in connexion, up to 1845. An account of the principles upon which it was established is published in the "*Verhandlungen des Gewerb-Vereins in Berlin*, Bd. I. s. 142." The original aim seems to have been to communicate directly practical instruction by means of large workshops for metal-working, carpentry, modelling, &c., the instruction in science being confined to that which appeared necessary for actual tradesmen. The accommodation in the workshops being limited, the maximum number of students was 90, each of the 3 classes having 30; although, practically, 40 were received, because it was found that about 10 were unfit for the instruction given, and were removed after trial. This removal was the more easy, as not only was the instruction gratuitous, but actual material support was given to the pupils by the State. The three classes into which the Institution was divided comprised the following subjects:—

Under class	-	-	Physics.
		-	Chemistry.
		-	Drawing.
		-	Mathematics and arithmetic.
Higher class	-	-	A second course of the same subjects, treated more fully.
"Supreme" class	-	-	Technology of various kinds, applied to the special trades—workshop practice.

The following are the numbers who passed through and obtained certificates of merit from the three classes in the first twenty-five years of their existence, viz., 1821–1846:—

	No. of pupils.	Certificates of merit.
Class I., or lower class	800	140
Class II., or higher class	556	380
Class III., or supreme class	534	

If we analyze the occupations of the 520 recipients of certificates, it will be seen that they were nearly all tradesmen, the analysis being as follows:—

210 Mechanics and mill makers.	13 Metal workers, engravers, &c.
91 No fixed occupations.	10 Weavers.
64 Carpenters.	5 Goldsmiths and tinplate workers.
60 Bleachers, dyers, chemists, &c.	3 Potters.
46 Builders.	1 Cooper.
17 Furniture makers.	

In 1845 Von Beuth ceased to be Director, and was succeeded by Pommerasche until 1848, and on his cessation there were two temporary Directors, until the appointment of the present Director Drückenmüller, in October 1849. Under this last Director great changes, both in the staff of professors and plan of the institution, have been made. These consisted in giving more of a collegiate and less of a school character to the Institution, the class of students being changed from that of tradesmen to managers of works and factories. The workshops, although still

* I am indebted to His Excellency Von Beuth and Privy Councillor Schubarth, as well as to Director Drückenmüller, for much information concerning this institution.

kept up at great expense, are not thought to be so essential to the instruction of the pupils as under the old system. The following are the present professors :—

Mathematics	-	-	-	Wölff.
Physics	-	-	-	Dove.
Chemistry	-	-	-	Rammelsberg.
Technology	-	-	-	Magnus.
Machinery	-	-	-	Wiebe and Fink.
Architecture	-	-	-	Löhde and Manger.
Free drawing	-	-	-	Freiberg.
Linear drawing	-	-	-	Pohlke.
Modelling	-	-	-	Kiss.
Design	-	-	-	Boettlicher.

The workshops are large and commodious, and well supplied with tools, and are under the management of one Director and ten experienced workmen; the "mechanics" attend them in the third year. In the first quarter, modelling in wood is taught; in the second, castings which may be made to the extent of between 3 and 4 tons in weight, the metal used being bronze or brass. During the rest of the time the pupil is engaged in the workshop making tools, turning lathes, and any special machinery ordered by Government. When any new machine of promise to technology is invented in foreign countries it is bought by Government, then sent to this Institution to be drawn and modelled, and is afterwards presented to a manufacturer, with the view of introducing it to the trade. The models for the museum are made in the workshop, according to scale, and accurate in detail; but they do not appear to be well arranged, and have no descriptive labels for the use of the public. In addition to the large workshops, there is a small one for carving, embossing, and inlaying metals; but it is not used directly for the instruction of the pupils; another workshop, however, for modelling in clay, plaster, &c., is in active operation. The budget for 1852 may be considered interesting, as it shows the manner in which the expenditure is divided.

	Thalers.	Subject-amounts. Thalers.
<i>A. Executive Staff :—</i>		
Drückenmüller, the Director, in addition to a free house	1,800	
Fickerman (Sub-director?)	800	
Wedding, librarian, &c.	400	
Assistant librarian and secretary	730	
Patskow, the porter	216	
Hoffman, servant and messenger	208	
Executive expenditure	- - -	4,154
<i>B. Professional Staff :—</i>		
Wölff - Mathematics	1,700	
Dove - Physics	600	
Rammelsberg - Chemistry	1,600	
Magnus - Technology	500	
Manger - Architecture	1,400	
Lohde - Idem, and architectural drawing	1,000	
First professor of machinery	1,400	
Wiebe - (second professor)	1,200	
Freiberg - Assistant professor (machine drawing)	600	
Kiss - Modelling	700	
Boettlicher - Design	500	
Expenditure on professors	- - -	11,200
<i>C. House Expenses :—</i>		
Heating, lighting, repairs, &c.	2,025	2,025
Carried forward	- - -	17,379

	Thalers.	Subject-amounts. Thalers.
Brought forward - - -	- - -	17,379
D. <i>Workshops, &c.</i> :—		
The Directors and workmen in the workshops -	5,130	
Material for the workshops -	1,570	
Allowance for laboratory material, &c. (actually 800) -	600	
Models, apparatus, &c. (actually 1,400) -	1,200	
Library books - - -	1,500	
Workshop, &c., expenditure - - -	- - -	10,000
E. <i>Money to Students, &c.</i> :—		
Money given to poor students for scientific jour- neys, &c. - - -	17,100	17,100
F. <i>Miscellaneous</i> :—		
Miscellaneous expenses, as medals, certificates, &c. -	321	321
		44,800

SUMMARY.

	Thalers.
Executive and professional staff - - -	15,354
House expenses - - -	2,025
Workshops, laboratory, library, models -	10,000
Students exhibitions and scientific journeys -	17,100
Medals, certificates, &c. - - -	321
	44,800

APPENDIX B.

POLYTECHNIC SCHOOL OF SAXONY.

A list of the professors and teachers in the Technical School of Dresden* may be of interest, as showing the division of subjects taught in similar schools. They are as follows :—

Hülse (Director).	Mechanical technology and national economy.
Schubert -	Roads, railways, bridges, harbours, building, higher machinery, astronomy, projects for machines and building.
Schlömilch	Analytical geometry, differential and integral calculus, higher mechanics.
Stein -	Technical chemistry and laboratory work.
Löwe -	German in the upper classes.
Heine -	Architecture and architectural drawing.
Hughes -	English.
Geinitz -	Geognosy, geology, mineralogy, zoology, botany.
Lösche -	Experimental physics, higher physics, theoretical chemistry.
Puschner -	Free and ornamental drawing.
Wenzel -	Modelling in clay, composition of ornaments, &c.
Leclerc -	French.
Tröger -	Surveying in field, plan and chart drawing.
Fort, C. -	Book-keeping and mercantile knowledge.
Kuschel -	Mathematics.
Wahoda -	German, political economy.
Erlor -	Laws of projection, perspective and machinery drawing.

* I have to express my obligation to Director Hülse and Professor Stein for much information regarding the schools of Saxony.

Fort, O. - Mathematics and mechanics.
 Hackel - Laws of machinery, mills, projects for machines, geometrical drawing.
 Nagel - Higher geodesy, practical surveying, plans and geometrical drawing.
 Röder - Modelling in wood.

Building School.

Hülse (Director).
 Arndt - Architecture, architectural drawing, projects for buildings.
 Kuschel - Mathematics, statics, dynamics.
 Puschner - Free and ornamental drawing.
 Wahoda - German.
 Erler - Projection, perspective, architectural drawing.
 Hackel - Physical science.

It has been mentioned in the body of the Lecture, that the expenses of this school are much lower than those of the Trade Institute at Berlin, and the following is its balance sheet:—

EXPENDITURE.			RECEIPTS.		
		Thalers.			Thalers.
Teachers' salaries	-	13,640	State grant	-	14,000*
Excursions for students	-	160	Students fees	-	3,100
Library	-	700	Rent of house let to Director	-	100
Materials for drawing and modelling	-	150			
Museum and collections	-	750			
Laboratory expenses	-	300			
Heating and lighting	-	600			
Repairs	-	500			
Domestics, &c.	-	400			
		17,200			17,200

Elementary Knowledge required by Pupils.

The following conditions for entrance are given as an example of the elementary knowledge which each student must possess before being admitted into a German Polytechnic school:—

General Conditions.—The student's age must be 15. He must have been vaccinated and confirmed, and be well grounded in the following subjects:—

A. *Arithmetic*, especially in raising powers and extracting roots, both of whole numbers and fractions; proportion; the fundamental rules of algebra, to equations of the first degree. B. *Plane Geometry*. C. *Natural History*, including a knowledge of indigenous families of plants and animals. D. *Geography and History*; the principal laws of mathematical and political geography, and the chief events in the progress of nations. F. *German*, so far as to show a readiness in expressing thoughts both orally and by writing. G. *Geometrical Drawing*, so as to show a ready use of drawing instruments, and their application to making constructions both by straight and curved lines. H. *Experimental Physics and Mineralogy*; an elementary knowledge in these is recommended previous to entering the preparatory division of the school, but is not an absolute condition for reception into it.

Examination of Candidates for the Service of the State.

Before the State grants employment to surveyors, engineers, mechanists or architects, and builders, the candidates must prove their qualifications by an examination before a Special Commission; and as this system is more or less pursued in all German States, the Saxon regulations may be quoted by way of general illustration. The general conditions are:—

1. The candidate must possess a certificate of his qualifications from one of the Technical schools.
2. He must show that he has been actually engaged for three years in the full practice of his profession.

These conditions being satisfied, he is subjected—1st. To an examination in the science and art of his profession. 2d. As to his powers of applying that science and

* The State grant usually amounts to 15,000 thalers.

art to the especial practical objects to be submitted to him. The knowledge required for the four chief Government employments above alluded to is as follows:—

For the Office of Surveyor.

Higher analysis.	Theoretical and practical geodesy.
Analytical mechanics.	Plan drawing.
Higher physics.	Astronomy.

These subjects include strict examinations in the higher analysis and mechanics; in theoretical astronomy, especially as to the determination of true and apparent time in given places, in the determination of the meridian and latitude of a place, and of the difference in longitude between two given places; trigonometrical surveying; chart and plan drawing; the theory and use of surveying instruments, as the barometer, levels, theodolites, circumferentor, plane table, compass, alidade, &c.

For the Office of Civil Engineer.

Higher analysis.	Geognosy and geology.
Analytical mechanics.	Roads, railways, hydraulic works, and plans for bridges, canals, railways, roads, &c.
Higher physics.	
Theoretical and practical geodesy.	

The examinations enter thoroughly into higher analysis and mechanics; mineralogy and geology; building materials; the theory and practice of roads and railways; the theory and practice of hydraulics and of foundations; the principles and practice of bridges, &c.

For the Office of Mechanist.

Higher analysis.	Motive powers.
Analytical mechanics.	Mechanical technology.
Higher physics.	Projects for machines.

The examination refers to an especial knowledge of the theory and construction of steam-engines; of the construction of mills; and of mechanical technology generally.

For the Office of Architect or Builder.

Higher analysis.	The history and æsthetics of architecture.
Analytical mechanics.	Architectural plans and projects.
Higher physics.	

In the examinations higher analysis and mechanics are used in reference to architecture generally, to building materials, plans, and construction of public buildings, their heating, lighting, ventilation, &c.

APPENDIX C.

POLYTECHNIC SCHOOL OF VIENNA.*

It has been mentioned in the Lecture that the technical part of this school contains 1,637 pupils, who are divided as follows:—

	Preparatory division.	Technical division.	Commercial division.	Total.
Matriculated students	419	870	95	1,384
Unmatriculated students	—	222	31	253
	419	1,092	126	1,637

* My information regarding the schools of Austria has been derived chiefly from Chevalier de Burg, the late Director of the Central School; from Dr. Redlenbacher, the Professor of Chemistry in the University of Vienna; and from the obliging attention of the officials of the school, who placed their books and documents at my disposal.

In addition to the general technical department, there is one for drawing, which is attended as follows :—

	Week days.	Sundays.
Preparatory drawing -	184	500
Manufacturing drawing -	86	90
Drawing for metal work - -	76	112
Machine drawing - - - -	14	29
	360	731

The other subjects, taught in the Sunday schools, and attended by 650 students, have already been given. Of all classes of students, therefore, there are 3,378.

The public and lecture collections of the school are efficient, and consist of the following subjects :—

- | | |
|--|---|
| 1. Raw materials and products. | 7. Mineralogical and geological collections. |
| 2. Cabinet of mechanical models. | 8. Trade collection of finished manufactures. |
| 3. Cabinet of physical apparatus. | 9. Agricultural collection. |
| 4. Collection of chemical products and preparations. | 10. The technical cabinet of the Emperor Ferdinand. |
| 5. Cabinet of mathematical instruments. | |
| 6. Architectural collection. | |

APPENDIX D.

BAVARIA.*

The scheme of instruction in the Polytechnic School of Munich has been given in the body of the Lecture; and it may be useful to append that of the two other head schools of Bavaria.

Scheme of Instruction at Nurnberg.†

COURSE I.			COURSE II.			COURSE III.		
Sum- mer.	Win- ter.	—	Sum- mer.	Win- ter.	—	Sum- mer.	Win- ter.	—
Hrs.	Hrs.		Hrs.	Hrs.		Hrs.	Hrs.	
4	4	Trigonometry.	5	5	Theory of equations; differential and integral calculus.	2	2	Higher mathematics.
2	4	Analytical geometry.				5	5	Mechanics.
2	2	Equations.				3	3	Machinery.
6	6	Descriptive geometry.	5	5	Mechanics.	8	8	Analytical chemistry.
3	-	Practical geometry.	3	3	Physics.			Architectural and machine drawing.
5	5	Physics.	8	8	Chemistry.	12	12	
8	8	Drawing.	12	12	Drawing.			

* For the information regarding the schools of Bavaria I am chiefly indebted to Professor Schaffhaeutl, the present Royal Commissioner of the Central School; to Dr. Alexander, the Director and Ministerial Referee; and to much courteous attention at the Ministry of Trade.

† Besides the above lectures practical instruction is given in workshops, the foundry, and laboratory.

Scheme of Instruction at Augsburg.

COURSE I.	COURSE II.	COURSE III.
Analysis; trigonometry; analytical and descriptive geometry. Physics. Drawing (architectural, machine, figure, manufacturing).	Differential and integral calculus. Analytical mechanics. Surveying. Technical chemistry. Architecture. Drawing (architectural, machine, plan, figure, manufacturing).	Applied mechanics. Analytical chemistry. Architecture. Machinery. Drawing (architectural, machine, figure). Mechanical workshops.

Building School at Munich.

As there is no example of a building school given in the body of the Lecture, I describe the general features of this school somewhat in detail, expressing my obligations to the Principal and to Professor Haindl for all the information which I possess regarding it. The school was established in 1823, and is chiefly intended for workmen, such as carpenters and masons who intend to be, or are, engaged in building; but it is also numerously attended by masters themselves. Persons of all nations are admitted, provided they possess the requisite elementary knowledge. In order to enable men engaged in the active pursuits of their trades to enter the school, the session is between the 11th November and the 19th March, a period when building is scarcely carried on in Germany. There is a very good collection of models made by the students themselves, the workshops being open from 8 A.M. until late in the evening. The school has nine professors, and had last year 143 pupils, but it has not yet recovered from the political convulsions of 1848, previous to which year it had 200 students, the number of whom diminished immediately to 55, in consequence of the disturbed state of the country. The school is conducted economically, the fee for the 4½ months course being only 13s.; the total cost of the school, which is defrayed by a local grant, being a little less than 200*l*. The subjects are not yet divided into special courses, the pupil being allowed to choose those which he desires to study; they are as follows:—

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. Free and linear drawing. 2. Plain and ornamental writing. 3. Arithmetic and the elements of geometry for beginners. 4. Plane and solid geometry and mechanics, with applied arithmetic for more advanced students. 5. Descriptive geometry. 6. Laws of building materials. 7. Heating, ventilation, &c. 8. Stone-cutting, and practice in modelling with plaster. | <ol style="list-style-type: none"> 9. Wood construction, consisting in drawing, projection, and modelling in wood. 10. Embossing ornaments, &c., in clay and plaster. 11. Laws of projection, including practice in planning for given subjects. 12. Contracting for the above. 13. The elements of general architecture. 14. Building laws and police. |
|---|---|

The school has a fund amounting to 10,000 florins, the yearly interest of which is devoted to sending one or two of the most promising pupils to foreign countries, to cull their experience, and bring it back to their "fatherland." The principal countries which seem to send workmen to this school to be educated are Hungary, Moldavia, Denmark, and Switzerland. The additional means of instruction in the school, besides those already mentioned, are,—

1. A valuable library, consisting chiefly of works on building, and of architectural plates of ancient and modern times.
2. A collection of 1,500 subjects for drawing.
3. A collection of subjects for modelling.
4. From 180 to 200 specimens of stone work.
5. From 70 to 80 subjects for the use of carpenters.
6. Workshops for modelling, stone-cutting, carpentry, &c.

APPENDIX E.

ECOLE CENTRALE DES ARTS ET MANUFACTURES.

This institution is so important in itself, and so interesting from its great commercial success, as a private undertaking in France, where similar schools are always supported by Government, that it has been referred to at length in the Lecture, and now some further details are inserted concerning it. We must accept the facts, that the students are only limited to 300 by the size of the building, and that manufacturers eagerly demand the certificated pupils of the institution, as convincing proofs of its importance to the industry of France. There is now appended, (1) a list of the distinguished professors of the school; (2) its general rules; and (3) the conditions of admission, or amount of elementary knowledge possessed by a candidate before he is accepted as a pupil.

PERSONNEL DE L'ECOLE.—ANNÉE 1851-1852.

M. Lavallée, Directeur de l'Ecole.

M. Empaytaz, ancien élève de l'Ecole Polytechnique, Directeur des Etudes.

Professeurs, Membres du Conseil des Etudes.

Dumas, C.	- (1829) Sénateur, Membre de l'Académie des Sciences	Cours de Chimie générale.
Olivier, O.	- (1829) Prof. au Conserv. des Arts et Mét., Président du Conseil des Etudes	Géométrie descriptive.
Péclet, O.	- (1829) anc. Inspect' général de l'Université	Physique industrielle.
Ferry	- (1830) Ingénieur civil	Métallurgie du fer et Technologie mécanique.
Perdonnet	- (1831) l'un des Administrateurs-Directeurs du chemin de fer de Strasbourg. Vice-Président du Conseil des Etudes	Chemins de fer.
Mary, O.	- (1833) Inspect. divis. des Ponts et Chaussées	Constructions et Travaux publics, Architecture.
Payen, O.	- (1835) Membre de l'Académie des Sciences, Prof. au Conserv. des Arts et Métiers	Essais commerciaux; Chimie industrielle et Chimie agricole.
Belanger	- (1836) Ingén. en chef, Profes. à l'Ecole des Ponts et Chaussées et à l'Ecole Polytechn.	Mécanique industrielle.

Professeurs.

Peligot	- (1835) Membre de l'Académie des Sciences, Prof. au Conservatoire des Arts et Métiers	Analyse chimique.
Thomas	- (1838) ancien élève de l'Ecole Centrale, Ingénieur civil	Machines à vapeur.
Burat (Amédée),	(1841), Ingénieur civil	Géognosie et exploitation des mines.
Masson	- (1841) Agrégé de la Faculté des Sciences	Physique générale.
Martelet	- (1841) ancien élève de l'Ecole Polytechn.	Analyse géométrique et Mécanique générale.
Doyère	- (1845) Professeur à l'Institut national agronomique de Versailles	Physiologie et Histoire naturelle appliquée à l'Industrie.
Faure	- (1851) ancien élève de l'Ecole Centrale, Ingénieur civil	Transformations du mouvement.
Polonceau	- (1851) ancien élève de l'Ecole Centrale, Ingénieur civil	Construction et établissement des machines.

Professeurs-Adjoints.

Cahours	- Examineur de sortie à l'Ecole Polytechn.	Chimie générale.
Sonnet	- Inspecteur de l'Académie de Paris	Mécanique industrielle.

Examineur d'Admission à Paris pour 1852.

Sonnet - Déjà nommé.

Quelques leçons de Technologie spéciale sont faites par :

- Alcan - - Ingénieur, ancien élève de l'Ecole Centrale, chargé de leçons sur les Matières textiles (préparation, filature et tissage de la soie, du coton, de la laine, etc.)
 Salvétat - - Ingénieur civil, ancien élève de l'Ecole Centrale, Chimiste à la Manufacture nationale de Sèvres, chargé des leçons sur la Poterie.

Chefs des travaux Chimiques.

- Favre - - Professeur agrégé à la Faculté de Médecine de Paris.
 Rigout - - Préparateur de Chimie organique à la Faculté de Médecine de Paris.

Chefs des travaux Graphiques.

- Thumeloup - Architecte.
 Tronquoy - Maître de Dessin à l'Ecole Polytechnique.
 Robert - - Adjoint.

Répétiteurs.

- | | | | | | |
|--------------|---|---|---|---|--|
| Daniel | - | Licencié ès sciences physiques | - | - | Physique générale. |
| Cahours | - | Déjà nommé | - | - | Chimie générale. |
| Fernique | - | Professeur de Mathématiques | - | - | Géométrie descriptive. |
| Priestley | - | Ingénieur, ancien élève de l'Ecole Centrale | - | - | Analyse géométrique et Mécanique générale. |
| Descloiseaux | - | Ancien élève de l'Ecole des Mines | - | - | Géognosie et exploitation des mines. |
| Faure | - | Déjà nommé | - | - | Métallurgie du fer. |
| Poinsot | - | Chef des travaux chimiques au Conservatoire des Arts et Métiers | - | - | Chimie industrielle. |
| Bénard | - | Ingénieur, ancien élève de l'Ecole Centrale | - | - | Constructions et travaux publics. |
| Sonnet | - | Déjà nommé | - | - | Mécanique industrielle. |
| Thomas | - | Déjà nommé | - | - | Physique industrielle. |
| Cornet | - | Ingénieur, ancien élève de l'Ecole Centrale | - | - | Chemins de fer. |
| Debonnefoy | - | Ingénieur, ancien élève de l'Ecole Centrale | - | - | Construction des machines. |

Préparateurs.

- Jacquelain - Licencié ès sciences physiques, Préparateur des cours de Chimie.
 Daniel - - Déjà nommé, Préparateur des cours de Physique.
 Leconte - - Aide-Préparateur de Chimie.

Service d'Administration.

- Fabre - - Caissier, chargé de la conservation du matériel.
 Latruffe - - Commis. d'ordre.
 Valette - - Commis.

Bibliothèque.

- Bibliothécaire.
 Perin - - Sous-Bibliothécaire.

Service de surveillance et de discipline.

- Rameau - }
 Cance - } Inspecteurs des élèves.
 Poujol - }
 Guillot - }

Médecin de l'Ecole.

- Cazenave fils, Professeur agrégé de la Faculté de Médecine de Paris, Médecin de l'Hôpital Saint-Louis.

The following extracts from the Statutes, in addition to the remarks in the Lecture, will sufficiently indicate the general character of the school, and of the subjects taught in it:—

STATUTS GÉNÉRAUX DE L'ECOLE.

§ I. But de l'Ecole.

1°. L'Ecole Centrale est destinée spécialement à former des ingénieurs civils, des directeurs d'usines, des chefs de fabriques et de manufactures; à alimenter l'industrie d'hommes capables d'apporter dans la direction de ses établissements et de ses grands travaux les lumières que fournissent les sciences physiques et mathématiques, non-seulement étudiées dans leurs doctrines les plus importantes et les plus générales, mais considérées surtout au point de vue de leur application pratique.

§ II. Institution de l'Ecole.

2°. L'autorité supérieure dans l'Ecole appartient à un directeur et à un Conseil des études, qui délègue une partie de ses pouvoirs à un directeur des études.

3°. Le directeur de l'Ecole demeure dans l'établissement. Il est chargé de l'administration et de la correspondance. Il règle tout ce qui est relatif aux recettes et aux dépenses de l'établissement. Il veille à l'exécution des statuts et règlements. Le directeur seul prend les engagements pour les divers emplois; mais il ne peut choisir le directeur des études, les professeurs et les répétiteurs que sur la présentation du Conseil des études.

4°. Le Conseil des études se compose de neuf professeurs et du directeur des études. Il se réunit au moins une fois par mois, sur la convocation de son président. Il a dans ses attributions tout ce qui est relatif à l'enseignement, aux études et aux travaux des élèves.

Le Conseil des études arrête le règlement relatif à l'enseignement et à la discipline de l'Ecole. Il peut le modifier suivant les circonstances.

Le Conseil admet ou rejette les candidats d'après les procès-verbaux de leurs examens. Il prononce à la fin de chaque année sur l'aptitude des élèves soit à passer dans une division supérieure, soit à recevoir le diplôme d'ingénieur ou le certificat de capacité.

Il présente à la nomination du directeur de l'Ecole les candidats pour la direction des études et pour les chaires vacantes. Il désigne chaque année les répétiteurs et l'examineur pour les aspirants à l'Ecole.

Les professeurs sont choisis, autant que possible, parmi les hommes joignant à la théorie une connaissance profonde de la pratique.

5°. Le Conseil des études, dans l'intervalle de ses séances, est représenté par un conseil d'ordre, composé du directeur des études et d'un professeur, au moins, désigné pour cette fonction. Le directeur de l'Ecole assiste à ses séances, qui ont lieu au moins une fois par semaine.

6°. Le directeur des études est chargé de l'exécution des décisions du Conseil des études. Il fait les ordres du jour nécessaires pour régler les études et pour maintenir la discipline dans l'Ecole.

7°. Les élèves peuvent réclamer par écrit auprès du Conseil des études; mais même, dans ce cas, les règlements et ordres du jour sont obligatoires sans délai jusqu'à ce qu'ils aient été modifiés.

Tout élève en entrant à l'Ecole prend l'engagement de ne faire partie d'aucune réunion qui aurait pour but de s'opposer à l'exécution des décisions prises par le Conseil des études ou par les directeurs. Il promet de ne prendre part à aucune coalition tendant à imposer aux élèves les décisions ou les volontés d'une partie quelconque d'entre eux.

8°. L'Ecole ne reçoit que des élèves externes.*

9°. Les élèves ne portent pas d'uniforme. (Arrêté ministériel du 17 Octobre 1849, rapportant celui du 10 Mars 1848.)

§ III. Enseignement.

10°. La durée du cours complet d'instruction à l'Ecole Centrale est de trois ans.

L'enseignement se compose des cours, des interrogations journalières, des travaux graphiques, des manipulations de chimie, de coupe des pierres et de charpente, de physique et de mécanique, des constructions, des problèmes, projets et concours partiels, des examens généraux.

11°. Pendant les trois années d'étude, tous les cours sont obligatoires pour les élèves; mais, à partir du milieu de la seconde année, les dessins, les manipulations et les projets se partagent en deux séries: l'une générale et l'autre relative à la spécialité à laquelle se destine chaque élève.

12°. Les spécialités sont au nombre de quatre, savoir:

1. Spécialité des mécaniciens. Construction et établissement des machines, arts mécaniques.
2. Spécialité des constructeurs. Construction des édifices, travaux publics, arts physiques: ponts, canaux, routes, chemins de fer; architecture civile et industrielle; chauffage, éclairage, salubrité des villes et des grands établissements.

* Hors du temps que les élèves sont obligés chaque jour de passer dans l'établissement, ils doivent se livrer chez eux à l'étude des notes qu'ils ont recueillies dans les cours, à la rédaction des Rapports, des Mémoires qui leur sont demandés, travail qui exige le calme de la retraite; et lorsque leur tâche est accomplie, ils emploient leurs courts loisirs à visiter des ateliers et des usines dont les travaux sont en rapport avec les diverses branches de l'enseignement de l'Ecole. Mais il est des familles qui craignent avec raison d'abandonner à eux-mêmes leurs fils, trop jeunes encore pour user avec sagesse de la liberté; le directeur de l'Ecole peut satisfaire à leur juste sollicitude en leur recommandant avec confiance une institution située dans le voisinage, et dont la destination spéciale est tout à la fois de préparer les jeunes gens qui aspirent à entrer à l'Ecole, et de recevoir en pension ceux qui en suivent les cours.

3. Spécialité des métallurgistes. Exploitation des mines. Métallurgie.
 4. Spécialité des Chimistes. Chimie. *Chimie minérale*: poteries, porcelaine, verrerie, minium, produits chimiques en général, acide sulfurique, acide hydrochlorique, soude, chlorure de chaux, aluns, sulfates de fer et de cuivre, chromates, salpêtre; art de l'essayeur; affinage des métaux précieux, etc., etc. *Chimie organique*, *Arts agricoles*: teinture, couleurs, vernis, acide pyroligneux, vinaigres, acétates, céruse, crèmes de tartre acide, tartrique, sucre de cannes et de betteraves, amidon, toiles peintes et papiers peints, distilleries, brasseries, huiles, graisses, cire, savons, tannerie, charbon animal, bleu de Prusse, gélatine, etc., etc.

Chaque élève de deuxième année doit déclarer, à la fin du premier semestre, quelle est, parmi ces spécialités, celle à laquelle il se destine.

13°. Des interrogations journalières sont faites par les professeurs et par des répétiteurs; les notes des examens restent en dépôt à la direction des études, où se fait le classement des élèves à interroger.

14°. Les travaux graphiques se composent de dessin architectural, de lavis, d'épures à règle, au compas et à l'échelle, et de croquis tracés à main levée et cotés, relatifs à tous les cours.

Une importance extrême est attachée à ces travaux, le dessin étant pour les ingénieurs un langage indispensable, et dont l'emploi doit leur être très-familier.

15°. Les manipulations de chimie sont assez nombreuses pour donner aux élèves une instruction positive dans cette science.

Les élèves de première année manipulent une fois par semaine dans les laboratoires, et, en outre, exécutent les expériences de physique les plus essentielles. Ils opèrent sous les yeux des répétiteurs attachés aux cours.

A partir du deuxième semestre de la deuxième année d'études, et pendant toute la troisième année, les élèves qui appartiennent aux spécialités *Chimie industrielle* ou *Métallurgie*, complètent leur instruction chimique en manipulant à tour de rôle dans les laboratoires d'analyse.

Les manipulations de 2° et 3° années sont surveillées par le chef des travaux chimiques, sous la direction du professeur d'analyse chimique.

16°. Enfin, on met à la disposition des élèves tous les matériaux nécessaires à la construction de quelques appareils d'art. Ils les établissent eux-mêmes, d'après les dessins qui leur sont donnés ou d'après les projets qu'ils ont étudiés.

17°. Pour rendre complet le système d'enseignement, on a joint aux éléments précédents des problèmes à résoudre pendant la première année. A partir de la seconde, les élèves sont chargés de dresser des projets de plus en plus compliqués qui les familiarisent d'abord avec les détails des constructions industrielles, et plus tard avec les dispositions d'ensemble qui sont les plus convenables dans chaque classe d'usines. Ces projets sont examinés par les professeurs dans des conférences.

18°. Indépendamment des interrogations faites pendant la durée des cours, les élèves soumissent à la fin de chaque année scolaire des examens généraux sur toutes les branches de l'enseignement.

Les résultats de ces examens, combinés avec ceux des interrogations qui ont lieu dans le courant de l'année, et en outre avec les notes prises pendant les manipulations et les expériences, celles qui sont données aux dessins et projets exécutés par l'élève, et enfin celles qui se rapportent à la conduite, forment un ensemble d'après lequel le Conseil des études prononce sur le passage dans une division supérieure des élèves de 1^{re} et 2^e année, suivant un classement par ordre de mérite, et sur l'aptitude des élèves de 3^e année à concourir pour le diplôme d'ingénieur.

19°. Les élèves ont à leur disposition une bibliothèque composée des ouvrages qui peuvent leur être nécessaires pour y faire les recherches relatives à l'exécution de leurs projets. La bibliothèque est ouverte le soir jusqu'à neuf heures pour tous les élèves de l'Ecole.

20°. Les cours de l'Ecole commencent, chaque année, le 10 Novembre pour la 1^{re} année, et le 2 Novembre pour la 2^e et la 3^e année. Ils finissent dans le courant du mois de Juillet.

Les examens généraux ont lieu à la fin de chaque cours et sont tous terminés du 10 au 20 Août.

Les vacances commencent après les examens généraux.

§ IV. Diplômes et certificats de capacité.

21°. Les élèves de 3^e année sont admis à concourir pour l'obtention du diplôme, par décision du Conseil des études, conformément aux règles tracées par l'art. 18.

22°. Les élèves entrent en concours le 25 Juin.

23°. Le programme d'un projet est rédigé pour chaque spécialité. Les élèves ont trente-cinq jours pour en exécuter les dessins, dans l'intérieur de l'Ecole, et rédiger le

Mémoire à l'appui. Enfin ils soutiennent un examen oral sur leur projet, qu'ils sont obligés de développer et de défendre en présence d'un jury composé de cinq professeurs au moins.

24°. Le concours terminé, les professeurs se réunissent en conseil et statuent sur les diplômes d'ingénieur et les certificats qu'il y a leur d'accorder.

25°. Le diplôme d'ingénieur civil est accordé aux élèves qui ont satisfait aux épreuves exigées pendant les trois années d'Ecole, et surtout à celles du concours qui termine les études. Le certificat de capacité est accordé à ceux qui n'ont satisfait qu'à certaines de ces épreuves.

26°. Tout élève admis au concours qui en a subi toutes les épreuves, et qui a échoué, peut s'y représenter les années suivantes aux époques fixées par le Conseil des études, en se soumettant aux autres règlements de l'Ecole, et sans être obligé de redoubler la troisième année.

27°. L'Ecole ne reconnaît comme anciens élèves que ceux qui ont obtenu le diplôme d'ingénieur ou le certificat de capacité. Il est interdit au directeur de l'Ecole et aux professeurs d'accorder aux autres élèves aucune espèce de certificat spécial.

28°. Tous les projets et Mémoires de concours appartiennent à l'Ecole et sont déposés à la bibliothèque pour servir à l'enseignement.

29°. Les élèves de la deuxième année doivent assister au concours. Le public peut y être admis.

Frequent allusions have been made in the Lecture to the necessity of demanding a sufficient amount of elementary knowledge, on the part of the pupil, before he is received into an industrial college. The demand has the double benefit of enabling the professors to devote their whole time to the industrial applications of science and art, and also of giving an impulse to schools of general education, which are thus converted into allies of, instead of being made antagonists to, schools of industry. The following conditions are, therefore, given in illustration of the elementary knowledge requisite for admission, although it is in this case chiefly confined to the mathematical sciences:—

PROGRAMME DES CONNAISSANCES EXIGÉES POUR L'ADMISSION À L'ÉCOLE CENTRALE.

Arithmétique.

Nombres entiers.—Les quatre opérations principales sur les nombres entiers.—Emploi du complément arithmétique pour substituer l'addition à la soustraction.—Un produit est indépendant de l'ordre de ses facteurs et de la manière dont ils peuvent être groupés s'il y en a plus de trois. Exemple : $a.b.c.d.e.f = e.b(d.a)(f.c)$. Conséquences de ce principe quand un ou plusieurs facteurs sont terminés par des zéros.—Le produit de deux nombres entiers a autant de chiffres qu'il y en a dans les deux facteurs ensemble ou un de moins.

Décomposition d'un nombre en ses facteurs premiers.—Le produit de plusieurs nombres premiers n'est divisible par aucun autre nombre premier.—Caractères de la divisibilité d'un nombre par 2, 3, 5, 9, et application dite *preuve par 9*.—Recherche du plus grand commun diviseur de deux nombres et en général de plusieurs nombres.—Détermination du plus petit multiple de plusieurs nombres.

Fractions ordinaires.—Définition des fractions.—Définitions de la multiplication et de la division, applicables aussi bien quand le multiplicateur et le quotient sont fractionnaires que lorsqu'ils sont entiers.—Divers usages de la division.

Toute fraction multipliée par son dénominateur produit le numérateur.—Le quotient complet de la division d'un nombre entier par un autre est une fraction qui a pour numérateur le dividende et pour dénominateur le diviseur; l'opération appelée division des nombres entiers donne la partie *entière* du quotient.—On ne change pas la valeur d'une fraction si on multiplie ou divise ses deux termes par un même nombre.—Réduire une fraction à sa plus simple expression.—Amener plusieurs fractions au plus simple dénominateur commun.—Addition et soustraction des fractions.

Produit de plusieurs fractions. Il est indépendant de l'ordre des facteurs.—Division d'un nombre quelconque par une fraction. On ne change pas le quotient en multipliant ou divisant le dividende et le diviseur par un même nombre entier ou fractionnaire.—La multiplication et la division des fractions se ramenant à des multiplications sur des nombres entiers, les élèves doivent être exercés à supprimer les facteurs communs aux deux termes de la fraction résultante avant d'effectuer les multiplications.

Si plusieurs fractions sont égales et qu'on les ajoute terme à terme, c'est-à-dire qu'on prenne pour numérateur la somme des numérateurs et pour dénominateur celle des dénominateurs, la nouvelle fraction est égale aux premières; mais si celles-ci sont

inégales, la nouvelle fraction obtenue est comprise entre la plus petite et la plus grande des fractions primitives. Application de ce théorème au cas particulier d'une fraction et de l'unité sous la forme $\frac{m}{n}$. — Propriétés et calcul de la moyenne arithmétique de deux et en général de plusieurs nombres.

Fractions décimales. — Les quatre opérations principales sur les fractions décimales

La division d'un nombre entier ou fractionnaire décimal par un autre se ramène toujours, par le déplacement des virgules décimales, au cas où le diviseur est un nombre entier terminé par un chiffre autre que zéro.

Transformation d'une fraction ordinaire en fraction décimale et réciproquement. — Notions principales sur les fractions périodiques.

Détermination du degré d'exactitude certaine du résultat d'une des quatre opérations principales, quand un ou plusieurs des nombres donnés ne sont qu'approximatifs à moins d'une demi-unité près de l'ordre de leur dernier chiffre.

Système métrique décimal. — Connaissance complète du système métrique décimal.

Les élèves doivent savoir tracer sur le tableau, sans l'aide d'aucune mesure, à moins d'un dixième près, la longueur d'un mètre, d'un ou de plusieurs décimètres, d'un ou de plusieurs centimètres.

Définitions de l'are, de l'hectare, du litre, du kilolitre, du gramme, du kilogramme, du tonneau de mille kilogrammes, tirées chacune immédiatement de la connaissance du mètre et de ses subdivisions. — Définition du franc.

Une quantité concrète étant rapportée à une unité quelconque du système métrique, trouver, par le simple déplacement de la virgule, l'expression de la même grandeur quand l'unité est prise parmi les multiples ou sous-multiples décimaux de la première, notamment quand le mètre carré et le mètre cube sont remplacés, comme unités, l'un par le décimètre carré, le centimètre carré..., l'autre par le décimètre cube, le centimètre cube..., et réciproquement.

Application des quatre opérations principales à des questions sur des quantités exprimées d'après le système métrique décimal.

Anciens nombres complexes. — Les quatre principales opérations sur les nombres complexes dans les cas les plus ordinaires.

Algèbre.

Les quatre règles sur les monômes, les polynômes et les fractions algébriques.

Résolution et discussion des problèmes déterminés du 1^{er} degré à une ou plusieurs inconnues, en insistant sur la pratique du calcul. — Faire voir que les solutions négatives satisfont algébriquement aux équations d'où elles sont déduites, et indiquer par des exemples le parti qu'on en tire dans la résolution des problèmes.

Proportions. — Ce qu'on entend par deux quantités commensurables. L'expression la plus simple de leur rapport est donnée par deux nombres entiers premiers entre eux. Deux fractions abstraites ou affectant une même unité concrète sont dans ce cas. — On ne change pas un rapport en multipliant ses deux termes par un même nombre plus grand ou plus petit que 1. — Ce qu'on entend par le rapport approché (par exemple à un centième, à un millième près...) de deux quantités de même nature qui peuvent être commensurables ou incommensurables.

Toute proportion entre des quantités commensurables deux à deux peut être mise sous la forme $mA : nA :: mB : nB$, m et n étant deux nombres abstraits, A et B deux quantités de nature quelconque. On peut déduire de cette considération toutes les propriétés des proportions.

Deux quantités variables dépendant l'une de l'autre, qu'entend-on lorsqu'on dit que les valeurs de la première sont directement ou réciproquement proportionnelles aux valeurs correspondantes de la deuxième? — Règles de trois directe, inverse.

Si une quantité z varie en raison directe de certaines variables $p, q, \dots$ et en raison inverse d'autres variables $t, u, \dots$, faire voir qu'on a $z = k \frac{p \cdot q \cdot \dots}{t \cdot u \cdot \dots}$, en désignant par k un coefficient constant qui se détermine quand on connaît un système de valeurs simultanées $z, p, q, \dots, t, u, \dots$ des variables.

Application : règle de trois composée.

Partage d'un nombre en parties proportionnelles deux à deux à des nombres entiers et fractionnaires donnés (procédé de la règle de société).

Etant connu le rapport d'une quantité à une autre, de celle-ci à une troisième, de la troisième à la quatrième, et ainsi de suite, trouver le rapport de la première à la quatrième. — Questions et procédés connus sous les noms de règles conjointe et d'arbitrage.

Extraction des racines carrée et cubique des nombres entiers ou décimaux, à quel degré déterminé d'approximation. Si l'on opère sur un nombre entier ou décimal, à quel

caractère reconnaît-on que le résultat est exact à moins d'une demi unité près de l'ordre du dernier chiffre?

Résolution et discussion des équations du 2^e degré et des équations bi-carrées à une inconnue.—Problèmes à plusieurs inconnues qui par l'élimination se ramènent aux cas précédents.

Binôme de Newton, dans le cas de l'exposant entier positif, fondé sur la théorie des combinaisons.

Puissances et racines des monômes.—Théorie des exposants négatifs ou fractionnaires.

Propriétés des logarithmes considérés comme exposants variables.—Usage des tables les plus simples.—Applications diverses en insistant, dans le cas de l'extraction des racines, sur la modification à faire subir à la caractéristique lorsqu'elle est négative.

Progressions par différence et par quotient.—Relations entre le premier terme, le dernier, la raison, le nombre des termes et leur somme.—Limite de la somme des termes d'une progression décroissante.—Insertion de moyens.—Questions principales d'intérêt composé, comprenant les annuités.

Notions sur l'homogénéité des équations algébriques entre des quantités concrètes.

Géométrie.

Mesures des droites, des arcs de même rayon, des angles à l'aide de celle des arcs ayant les sommets pour centres.

Propriétés des perpendiculaires, des obliques, des parallèles. On admet comme évident qu'une perpendiculaire et une oblique à une même droite se rencontrent.

Somme des angles d'un triangle et d'un polygone quelconque.

Condition de l'égalité des triangles et des figures rectilignes.—On distinguera pour les figures situées dans un même plan, l'égalité directe de l'égalité par renversement qui a lieu quand l'une des figures ne peut coïncider avec l'autre qu'en la détachant du plan et la retournant; deux figures planes dont les points se correspondent symétriquement par rapport à un axe, sont dans ce dernier cas.

Lignes proportionnelles qui résultent de droites coupées par des parallèles.—Similitude (directe ou par renversement) des triangles et des figures planes rectilignes.—Bissectrice d'un angle intérieur ou extérieur d'un triangle.—Deux droites antiparallèles par rapport à un angle déterminent deux triangles semblables par renversement.

Propriétés du triangle rectangle.—Relation numérique entre les trois côtés d'un triangle quelconque et la projection d'un côté sur l'un des deux autres.—Autre relation entre les trois côtés et la ligne droite qui joint un sommet au milieu du côté opposé.

Tracé de la circonférence par trois points.—Tangente.—Conditions pour que deux circonférences soient l'une extérieure ou intérieure à l'autre, pour qu'elles se touchent ou se coupent; propriété de la corde commune et de la ligne des centres.

Détermination du nombre de degrés d'un angle par celui des arcs que ses côtés déterminent sur une circonférence qu'ils rencontrent ou touchent.

Tangente à deux cercles.—Cercle tangent à une ou plusieurs droites.

Si une droite tourne dans un plan en passant par un point fixe et rencontrant une circonférence, les deux distances du point fixe aux intersections simultanées sont deux variables réciproquement proportionnelles.

Moyenne proportionnelle entre deux droites (divers procédés).—Partage d'une droite en moyenne et extrême raison. Trouver l'expression numérique de chaque partie, la ligne entière étant prise pour unité.

Trouver graphiquement la longueur d'une ligne exprimée algébriquement en fonction de lignes connues soit sans radicaux, soit avec des radicaux du 2^e degré.

Propriétés principales du parallélogramme, du losange, du trapèze, des polygones réguliers.—Rapports des côtés du carré, de l'hexagone régulier, du triangle équilatéral, du décagone régulier, au rayon du cercle circonscrit.

Calcul du rapport de la circonférence au diamètre.

Relation entre le nombre de degrés d'un arc, sa longueur et celle du rayon.

Calcul des aires des figures planes et rectilignes.—De l'aire du cercle, d'un secteur.—Rapport des aires des polygones semblables, de deux cercles, de deux secteurs.—Tracé des figures planes, leur réduction et leur amplification dans un rapport donné.—Echelles.

Propriétés d'une ou plusieurs droites perpendiculaires à un plan.—Mesure de l'inclinaison d'une droite par rapport à un plan.—Mesure de l'angle de deux plans.—Parallélisme des droites et des plans.—Propriétés principales des angles polyèdres.—Etant données les trois faces d'un angle trièdre, déterminer ses trois angles dièdres, et réciproquement....—Etant données deux faces et l'angle dièdre compris, déterminer la troisième face.—Lignes proportionnelles résultant de l'intersection de droites coupées par des plans parallèles.

Notions générales sur la similitude, comprenant comme cas particulier les figures planes.*

* Un système de points M, N, P,... (formant soit des lignes, soit des surfaces, soit un ou plusieurs corps), étant situé d'une manière quelconque dans l'espace, si l'on prend un point

Propriétés principales des polyèdres les plus simples, du cylindre et du cône de révolution, de la sphère.—Trouver le rayon d'une sphère par une construction plane.

Somme des aires des faces latérales d'une prisme, déterminée par le périmètre de sa section droite et la longueur commune des arêtes latérales; application à la surface convexe d'un cylindre.—Surface convexe du cône droit, du cône tronqué, d'une calotte sphérique, d'une sphère.—Rapport des surfaces des corps semblables.

Volume des corps terminés par des plans.—Volume d'un prisme triangulaire à bases parallèles ou non, soit en fonction de l'aire de l'une des bases et des hauteurs relatives à cette base, soit en fonction de l'aire de la section droite et des longueurs des arêtes latérales.

Volume du cylindre droit, du cône, de la sphère, d'un segment sphérique en fonction de sa hauteur et du rayon de la sphère.

Rapport des volumes des corps semblables.

Dessin.

Etudes de dessin au trait et à la règle; études de dessin à main levée; études de lavis d'architecture.*

Observations.

Toutes les fois qu'il s'agira de démontrer l'égalité de deux rapports entre des quantités qui peuvent être incommensurables, on démontrera que leurs rapports approchés à un même degré d'approximation sont toujours égaux.

On préférera pour la géométrie curviligne les démonstrations par les infiniment petits ou par les limites.

Les élèves devront être exercés à traduire en nombres tous les théorèmes de la géométrie qui en sont susceptibles, et à en faire des applications.

Tout progrès à l'Ecole Centrale est impossible sans une bonne instruction préparatoire. C'est dans l'intérêt des jeunes gens qui s'y destinent qu'on publie le programme un peu développé des connaissances indispensables; mais pour ceux qui, avant leur entrée à l'Ecole, peuvent étendre leurs études au delà du strict nécessaire, le Conseil des études les engage à acquérir quelques notions sur les éléments de géométrie descriptive, sur ceux de la géométrie analytique, comprenant la trigonométrie rectiligne fondée sur la théorie des projections;† enfin sur les éléments de la physique et de la chimie. Il les engage aussi à donner tous leurs soins à l'art du dessin, dont l'ingénieur civil ne saurait se passer.

Le Conseil de l'Ecole a reconnu que beaucoup d'élèves manquaient en arrivant de l'habitude de prendre ces notes à l'amphithéâtre. Il invite les jeunes gens qui se préparent pour l'Ecole à prendre cette habitude de bonne heure, et il engage MM. les Professeurs des Ecoles préparatoires à surveiller cette partie de leur éducation.

S aussi quelconque (pouvant comme cas particulier être l'un de ceux du système); qu'on mène les droites SM, SN, SP,...et que sur ces droites, prolongées au besoin, on porte à partir du point S les distances SM', SN', SP',...proportionnelles à SM, SN, SP,...et dirigées respectivement dans le même sens; les points M', N', P',...ainsi obtenus formeront un système semblable au système M, N, P, et semblablement placé par rapport au point S qui s'appelle pôle commun de similitude. Les points M', N', P',...sont respectivement les homologues des points M, N, P,...Les droites telles que M'N' et MN, qui joignent deux points d'un système et leurs homologues dans l'autre, sont des droites homologues. Enfin deux plans passant l'un par trois points d'un système et l'autre par les trois points homologues du système semblable, sont deux plans homologues. Cela posé, on démontre : 1°, que, dans deux systèmes semblables et semblablement placés, deux droites homologues quelconques sont parallèles, et que leurs longueurs sont entre elles dans le rapport des distances de deux points homologues quelconques au pôle commun; 2°, que les plans homologues sont parallèles; 3°, que les angles plans, dièdres ou polyèdres homologues sont égaux.—Deux systèmes peuvent être semblables sans être semblablement placés; mais il faut pour cela qu'il soit possible d'en construire un troisième égal à l'un d'eux et en même temps semblable à l'autre et semblablement placé par rapport à un pôle commun. On démontre aisément d'après ces principes que deux systèmes semblables à un troisième sont semblables entre eux.

* L'importance du dessin pour toutes les spécialités (mécaniciens, constructeurs, métallurgistes ou chimistes) a décidé le Conseil des études à ajouter cette condition d'admission au programme de 1840. Ainsi préparés, les élèves se livreront avec beaucoup plus de fruit aux nombreux travaux graphiques que l'enseignement de l'Ecole exige.

† Les élèves peuvent prendre pour guide, en cette partie de leurs études, l'ouvrage intitulé *Résumé des Leçons de Géométrie analytique et de Calcul infinitésimal*, par M. BELANGER, professeur à l'Ecole Centrale.

APPENDIX F.

TECHNICAL INSTITUTE OF COPENHAGEN.*

In Appendix D. reference has been made to a Bavarian school for the instruction of carpenters, masons, and others engaged in building; and the Technical Institute of Copenhagen is here described as a similar institution for artisans generally. The chief object of the institution, which owes much of its success to the unwearied labours of the veteran Academician Hetsch, is to teach drawing in its application to special branches of industry. It is, in fact, a systematized mechanics institute, and a people's school of design, not devoted to designers only, but to artisans of every class. The income of the school is very moderate, being at present only 366*l.*, all of which, with the exception of 500 rixbank dollars, is furnished by subscriptions and fees. This income is, however, insufficient, and its smallness prevents the natural development of the school. Cramped, however, as the school is by its limited means, there were on my visit no less than 15 teachers and 520 scholars. The fees paid by the latter are small, varying from 1 to 3 dollars per quarter. There are two classes of students, "the confirmed" and "the unconfirmed." Much importance is attached in Denmark to the rite of Confirmation, the attestation of which is considered an essential moral testimonial for employment; hence the above division of scholars is a common one in industrial schools, but really signifies little more than that the ages are below or above 16. Out of the 520 pupils attending during my visit to the school, only 80 were unconfirmed or were youths under 16; the remainder being artisans in full employment, or who were being educated for a trade. The latter attend the school all day, the former spend their leisure hours there, chiefly in evening classes. The subjects taught are as follows.

Subjects taught at the Technical Institute.

Hours in a week.	Classes.	SUBJECTS.
Each class meets twice in the week for two hours each time.	A.	Elementary drawing.
	B.	Drawing, for carpenters.
	C.	Drawing, for masons.
	D.	Modelling in clay and wood; wood-cutting.
	E.	Drawing, for cabinet-makers, upholsterers, and turners.
	F.	Drawing, for tinplate workers, lockmakers, and gunsmiths.
	G.	Lithography and engraving.
	H.	Drawing, for harness-makers, wheelwrights, and carriage builders.
	I.	Drawing, for machine-makers, watchmakers, and opticians.
	K.	Chiselling and embossing.
	L.	Drawing, for goldsmiths, coppersmiths, lamp and gasfitters, hardware workers, and glaziers.
	M.	Ornamental drawing, for porcelain painters, carpet manufacturers, bookbinders, and fringemakers.
	N.	Geometrical, free, and ornamental drawing for the "unconfirmed."
4	O. & P.	Elementary drawing.
16	Q.	Decorative painting.
14	R.	Drawing for builders.
7	S. T.	Drawing for journeymen and apprentices.
5	U.	Mathematics.
2	V.	Building materials.
1	X.	Practical arithmetic.
1	Y.	Book-keeping, contract reckoning, &c
1	Z.	Physics.

* I regret that the necessity of keeping the Lecture within the usual limits prevents me entering into the extensive information on general education in Denmark furnished to me by my many kind friends in Copenhagen, among whom I would express my obligations to Professor Forchammer, Academician Hetsch, Magister Hammerich, Professors Steenstrup, Scharling, Jorgensen, and Hammel. I would also recall with pleasure the polite attention and facilities offered to me by Mr. Simoni, the Minister of Worship and Education and Commander Steen Bille, the Minister of Marine.



GOVERNMENT SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

MUSEUM OF PRACTICAL GEOLOGY.

2nd Session. 1852-53.

THE importance of the mineral wealth of the United Kingdom far exceeds that of any other European State, and furnishes four ninths of the raw mineral produce derived from all Europe. Although the annual value of the mineral produce of this Kingdom amounts to 24,000,000*l.*, and the capital and labour employed in its extraction and application represent a much larger sum, no school having for its especial object the instruction of persons engaged in mining operations had, until last year, been established in the United Kingdom.

Mining Schools have long existed in France, Russia, Prussia, Saxony, Austria, Spain, Sweden, and other countries even less connected with mining; and their practical value is recognized by the fact, that the respective Governments of these States have found it necessary to develop still further the educational resources of such institutions. The want of similar establishments in this country has long been felt in mining districts, and has been expressed both in Parliament and in memorials addressed to the Government. In the Report of the Committee

of the House of Lords (1849), the Committee observe that "among those best qualified to speak upon this point, a want appears to be felt of facilities for acquiring mining education, such as are provided by the mining schools and colleges established in the principal mining districts of the Continent, apparently with the most beneficial effects." Memorials have been presented from the principal mining districts of the Kingdom, urging this want, and indicating the Museum of Practical Geology as the proper institution to be converted into a Mining School. In consequence of these representations, and of the enlargement of the Museum, the Government have applied the resources of the institution to public instruction in Mining, and in the applications of Science to the Arts.

Although the intention always was entertained, as shown by the name of the school, to include instruction in the applications of Science to the Arts, various circumstances have occurred which have induced the Professors to give prominence to this kind of instruction, as well as to the mining education so much required by this country. A strong feeling on the part of the public has been manifested for the establishment of schools professing instruction in the Arts. This feeling has found expression in memorials to the Commissioners of the Exhibition from Birmingham, Bristol, Hull, Nottingham, Sheffield, and other towns; and the Educational Council of this school have thought it expedient to enlarge the character of the instruction, so as to include the more important applications of the Sciences professed by the Lecturers to the Arts and useful purposes of life. The Museum has in consequence been enriched with illustrative collections of the progressive stages of mineral manufactures, its foundation at present not enabling it to include the organic manufactures, which are, however, illustrated by the lecture collections of the individual Professors.

The Laboratories and working rooms of the several departments are so arranged and organized, that systematic studies in Chemistry, Metallurgy, Geology, Palæontology, Physics, Mineralogy, and Mining, may be entered upon with great

advantage under the direction of the officers of the respective departments. The Museum itself is of an essentially practical character, and was primarily intended to bring Science to bear on Geology in its application to the useful purposes of life; its officers were selected with a view to carry out the educational character of the institution, recognized shortly after its formation by an official letter of the Chief Commissioner of Her Majesty's Woods, and sanctioned by the Lords of the Treasury.

The following is a list of the officers entrusted with the courses of instruction :

PRESIDENT.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.	
CHEMISTRY, applied to the Arts and Agriculture -	<i>Lyon Playfair</i> , Ph. D., F.R.S.
NATURAL HISTORY, applied to Geology and the Arts - - - - - }	<i>Edward Forbes</i> , F.R.S.
MECHANICAL SCIENCE, with its application to Mining - - - - - }	<i>Robert Hunt</i> , Keeper of Mining Records.
METALLURGY, with its special applications - - -	<i>John Percy</i> , M.D., F.R.S.
GEOLOGY, and its practical applications - - -	<i>A. C. Ramsay</i> , F.R.S.
MINING and MINERALOGY - - - - - }	<i>Warrington W. Smyth</i> , M.A., F.G.S.

The education contemplated in this School differs essentially from that given in colleges, where general education is the primary object. Although it is intended to give general instruction in Science, to those who may require elementary knowledge, still, the chief object of the Institution (to which everything else is made subsidiary) is to give a practical direction to the course of study, so as to enable the student to enter with advantage upon the actual practice of Mining, or of the Arts which he may be called upon to conduct. The students forming the different classes are subjected to regular and frequent examinations, both written and oral, in addition to those which are required for the Duke of Cornwall's Exhibition. As an example of these examinations a few of the papers are appended. It may therefore be desirable to call attention to the peculiar features of the Institution, and to the Courses of Lectures to be given by the respective Professors.

The Museum.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum, has afforded great facilities for making complete collections illustrative of the applications of Geology to the useful purposes of life. These collections contain an extensive series of rocks stratigraphically arranged, with reference to their mode of accumulation, and the subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used for constructing public works and buildings, and of those employed for ornamental purposes, or for the useful arts in connexion with chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are carefully exhibited, and illustrations of the finished products are also displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiar excellences of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of working carried on in different districts. The Museum is open to the Public for the first three days of the week, the remaining days being reserved for study.

Geological Surveys.

The Geological Surveys of the United Kingdom are carried on under the general direction of Sir H. T. De la Beche, and their central office is at the Museum. In this office the maps and sections are prepared and deposited. The field surveys are carried on in the localities under examination for the time being, and it is contemplated to communicate instruction in the field in the various departments of Geological Surveying, under the Mining, the Geological, and the Palæontological Professors.

Office of Mining Records.

This office, superintended by Mr. Robert Hunt, is established for the preservation of Mining Records. The absence of these needful documents was found to be the cause of much waste, in attempts to work in localities where there was little prospect of success, or where from a want of proper knowledge of the old workings much useless expenditure was incurred. A large collection of plans and sections of mines, and many important statistical mining details, are deposited in this Office, and are made available for the instruction of students.

Laboratories.

Two Laboratories, one for General, Practical, and Analytical Chemistry, under Dr. Lyon Playfair, the other for Metallurgy and Assaying, under Dr. Percy, are established in the Museum. Students will, under certain regulations, be admitted into the Laboratories for the purpose of receiving instruction in the analysis of minerals and ores, and of the methods used in applying them to useful purposes in the Arts.

Unless the student has already become acquainted with Practical Chemistry, it will be requisite to pass through the Chemical Laboratory before entering that for Metallurgy, as the latter requires previous chemical knowledge before its study can be usefully entered upon.

Palæontological Department.

As the relative age and sequence of geological formations are, to a great extent, determined by the fossils they contain, it has been found necessary, in the prosecution of the Geological Survey, to attach a department of Natural History, under the direction of Professor E. Forbes, where the organic remains contained in the sedimentary rocks of the British islands may be examined and preserved. Extensive collections of these fossils are arranged, and used for the instruction of students.

The following Courses of Lectures will be given during the Session :—

Chemistry.

The instruction in Chemistry is given both by Lectures and in the Laboratory. The lectures explain the general laws of chemical affinity and combination, the physical forces connected with chemical phenomena, and their application to useful purposes. The elementary bodies and their compounds are discussed, and especial importance is given to the practical appliances of the different substances described. The processes used in the chemical arts, and the manufactures chiefly depending on the application of chemical principles, are treated of in detail. The chemical facts of importance in their applications to mining and engineering, in the treatment of soils, and the conversion of mining products into substances useful in the Arts, are fully discussed. Organic Chemistry is so far entered upon, as is sufficient to enable the student to study more fully this important branch of the science; and its applications to the Arts and to Agriculture receive especial attention. In the Laboratory the students are taught the processes of qualitative and quantitative analyses.

Natural History applied to Geology.

The subjects of this Course include the principles of Natural History, considered especially in their bearing on geological evidence; the organization of extinct creatures compared with and illustrated by that of existing animals and plants; the history of the successive aspects of animal and vegetable life during the different geological epochs; the examination and description of organic remains, and the application of them to the determination of strata. The practical bearings of Natural History on the Arts will be illustrated in a separate Course.



Mechanical Science.

This Course will embrace a full consideration of the mechanical powers and the laws of motion, with illustrations taken from such sources as appear to furnish the largest amount of practical information. The laws by which the motive powers applied to machinery are regulated, will receive close attention and ample illustration.

The phenomena of Heat and Light, and the application of our knowledge of these physical forces to purposes of utility, together with Electricity in all its modifications of condition, and particularly Magnetism under the new and important aspects which recent discoveries have given it, will form the subject of examination. The explanations of natural phenomena afforded by Physical Science are necessarily included in this Course.

Geology.

This Course includes the proofs of the origin of stratified and igneous rocks, with an account of the more important substances entering into their composition, and an explanation of geological terms. The terrestrial actions now in progress are also described, including the degradation and denudation of land, earthquakes, volcanoes, areas of elevation and depression, &c. &c. Also, a descriptive account of the whole series of geological formations, showing their stratigraphical order and manner of formation, the laws by which these are determinable, and their general economic applications. Especial attention is given to geological surveying and its economical bearings.

Metallurgy.

The course of instruction in Metallurgy consists of Lectures and practical demonstrations in the Laboratory. The Lectures embrace the following subjects:—a description of the metals

and such of their compounds as are of metallurgic importance ; ores ; modes of extracting the metals from their ores ; furnaces, crucibles, &c., and the materials used in their construction ; fuel ; fluxes ; slags ; methods of assaying ; alloys. The smelting of iron, copper, and lead, and the manufacture of steel, are discussed at considerable length ; as also is the treatment of silver ores by the "wet" and "dry" ways, and the refining and "parting" of the precious metals. The important branch of Electro-metallurgy is treated of in detail. The principles involved in metallurgic processes are expounded with special reference to practical application.

Mineralogy.

The Course embraces Crystallography and the physical properties of Minerals, treated principally with a view to the practical discrimination of the substances considered by this science ; the elements of the Chemistry of Mineralogy, with the use of the blowpipe, and such simple tests as fall within the province of the field mineralogist, and the Physiography, or systematic description of Minerals, with particular reference to their mode of occurrence, and the uses to which they are applied.

Mining

Involves general considerations on the principles and management of subterraneous workings, the Practice of Mining in this and other countries being taught under the following heads :— Boring, and preliminary researches ; Tools, employed in mining ; shafts and sinking ; levels and driving ; the methods of securing excavations by masonry, timbering, and tubbing ; "exploitation," or the working away of veins and strata ; transport and winding, with the machinery and apparatus required ; pumps and pumping engines ; ventilation ; and the mechanical preparation or dressing of ores.

H.R.H. The Duke of Cornwall's Exhibition.

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted annually two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, at the end of the first Session. It is held by the successful competitor for two years.

Working Men's Lectures.

Lectures intended for Working Men, and explanatory of the collections of the Museum, are delivered occasionally during the year, and to these Lectures the Students are admitted.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of eventually obtaining the diploma of the Institution, must be at least 16 years of age, and will be required to bring certificates or other evidence of their having received a sufficient preliminary education. They shall pay *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures extending over two years, and field instructions, according to the regulations of the Institution; and shall have the privilege of studying in the Museum and in the Library.

The charge for instruction in the Laboratories (which is not included in the above) is *thirty pounds* for the Session of ten months, or *fifteen pounds* for the Term of five months. The Laboratories are open to Occasional as well as Matriculated Students.

OCCASIONAL STUDENTS will be admitted to the Lectures on payment of *four pounds* for each Course of above 30 Lectures, and *three pounds* for the Course of 30 and under.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, in the Queen's or the Honorable East India Company's Service, are admitted on similar terms.

Field instruction in Geology, Mineralogy, and Palæontology will be given to a limited number of OCCASIONAL STUDENTS, at a charge of *five pounds* per month.

The Session will commence on Wednesday the 3d of November, at Three o'clock, with an Introductory Address by Dr. Playfair.

Particulars respecting the times of Lectures, and all other information, may be obtained by application to Mr. TRENHAM REEKS, Curator of the Museum of Practical Geology, Jermyn-street, London.

APPENDIX.

The following papers are given as an example of the written examinations.

SESSION 1851-52.

CHEMICAL EXAMINATION.

12th May 1852.

1. What is the absolute evaporating power of a Coal of the following composition?—

Carbon	-	-	-	84.72
Hydrogen	-	-	-	6.43
Nitrogen	-	-	-	1.21
Sulphur	-	-	-	0.84
Oxygen	-	-	-	4.80
Ashes	-	-	-	2.00
				100.00

2. If 100 grains of the above Coal be burned in air, what bulk of air is required for the combustion? What products result from it? What is the weight of each product, and what the bulk of Carbonic Acid produced?

3. Explain the Dutch and French methods for making White Lead, the theory of the processes, and the formulæ of the products.

4. In what respect do air limes and hydraulic limes differ? Explain the manner in which each respectively acts.

5. The following substances being mixed together in powder, how would you distinguish both Acids and Bases?—

Arseniate of Baryta,
Selenide of Silver,
Chromate of Lead,
Silicate of Lithia,
Stannate of Soda,
Tartrate of Antimony.

6. Describe the relation between specific heat and atomic weight.

7. The following observations are made in analysing a gas :—

Observations.	Volume.	Temp.	Baro- meter.	Col. of Mer- cury above that in trough.	Corrected vol. at 0° C and 1 Metre Pressure.
Gas used (moist) - -	114.0	16.0	761.4	72.1	72.8
After absorption of } Carbonic acid (dry) }	111.4	15.8	760.6	74.7	72.2
After absorption of } O (dry) - - }	97.5	15.5	749.9	89.8	60.0
Gas used (moist)- -	78.6	15.4	750.6	226.1	38.1
Oxygen admitted (moist)	156.3	15.3	751.0	148.1	87.3
After Combustion (moist)	130.0	15.5	751.0	174.7	69.3
C O ² being absorbed } (dry) - - }	113.9	15.3	751.2	191.0	60.4
Hydrogen admitted (dry)	273.2	14.6	752.3	32.2	—
After Combustion (moist)	163.8	14.4	752.3	140.7	—

Correct the two last observed volumes for temperature, pressure, and tension of aqueous vapour, giving the corrected volumes at 0°C and 1 metre pressure. Calculate from the numbers in the last column, the composition of the mixed gases in 100 parts.

8. A salt containing potash, lime, sulphuric acid, and water, being analysed gave the following results :—

10.05 grs. of the salt gave 3.05 grs. carbonate of lime, and

14.85 grs. chloride of platinum and potassium.

9.28 grs. of the salt gave 0.51 grs. water, and 13.22 grs. sulphate of barytes.

What is the composition of the salt in 100 parts, and what is its probable formula?

LYON PLAYFAIR.

EXAMINATION IN NATURAL HISTORY APPLIED TO GEOLOGY.

13th May 1852.

1. Explain the terms *Species* and *Genus*.
2. What do we mean by *Provinces in Time* and *Provinces in Space*?
3. Enumerate the *principal groups* of organized beings according to their relative value with respect to Geological evidence.
4. What *portions of the bodies* of Vertebrata, Articulata, Mollusca, and Echinodermata are likely to be preserved in the fossil state?
5. Enumerate and define the *orders* of Corals, according to the classification of Milne Edwards, and Haime; state their geological distribution, and the amount and nature of the evidence they severally afford respecting the climates of past epochs.
6. State the distinguishing characters of the *orders* of Mollusca.
7. Enumerate and define the *extinct genera* of Echinidæ; and state the geological distribution of each.
8. Enumerate and define the *tribes* and *genera* of Brachiopoda, of which species occur in a fossil state; and give the geological range of each.
9. Enumerate and define the *genera* of Tetrabranchiate Cephalopoda. State the characters and geological range of the sub-divisions (according to Von Buch) of the genus Ammonites.
10. Explain the structure of a Trilobite, and enumerate and define the leading *tribes* of Trilobites.
11. What are the *genera* of Invertebrate animals that usually occur in a stratum of fresh water origin?
12. What *genera* of Radiata and Mollusca are exclusively Palæozoic?
13. What *genera* of Radiata and Mollusca are exclusively Mesozoic?
14. Describe minutely the specimen placed before you.

EDWARD FORBES.

EXAMINATION IN MECHANICAL SCIENCE.

14th May 1852.

1. Give an example of simple and of compound Motion, and explain the parallelogram of Forces.
2. Define the laws of Gravitation, and examples of each law.

3. A Stone is liberated at the height of 26,000 feet above the level of the sea ; neglecting the resistance of the air, in how many seconds will it fall to the ground, and what will be its final velocity ?

4. A body is projected vertically from the earth with an initial velocity of 240. Define its velocity during each second of ascent. At the end of how many seconds will it begin to fall ?

5. Describe the different phenomena produced by superficial attraction, or the adhesion of, and to surfaces.

6. Give the laws regulating the motion of a pendulum under different conditions of length.

7. Define the laws of the pressure of slightly elastic fluids, and describe their application in the Hydraulic Press.

8. Upon what does the action of the Hydraulic Ram depend ?

9. In a vessel kept constantly full of water, there are orifices at the depths respectively of 3, 5, and 9 feet. Give the ratio of the velocity of efflux from each.

10. Give the laws of atmospheric density and elasticity, and the relation of volume to the compressing force.

11. Upon what principle depends the application of the Barometer in measuring the heights of mountains ?

12. Describe the operation of Steam in an Engine working "expansively" ; and the differences between a single acting and a double acting Steam Engine.

13. Give some examples illustrating the conditions of sensible and latent heat.

14. Define the spaces occupied in the prismatic spectrum by the luminous, calorific, and chemical forces.

15. Define the terms Chromatic Aberration and the aberration of Sphericity, and the principle of the construction of achromatic lenses.

16. What are the conditions of a charged Leyden Jar, and point out some analogous conditions in natural phenomena ?

17. Define the expressions, *quantity*, and *intensity* as applied to Voltaic Electricity ; and describe the Voltaic arrangements necessary to produce these conditions.

18. Give the law of electro-chemical decomposition.

19. What is the relation between the mechanical power of an electro-magnet and the chemical action in a voltaic battery ?

ROBERT HUNT

EXAMINATION IN MINERALOGY.

15th May 1852.

1. What portions of the Inorganic Kingdom are considered by modern authors as belonging to the province of Mineralogy?
2. Give the derivation and meaning of the word *crystal*, and the reason for crystals being looked upon as the *individuals* of the inorganic world.
3. Define a *rhomb*, a *pyramid*, a *tetrahedron*, and an *octohedron*.
4. Describe the method of projection applied to the drawing of crystals, and draw a cube on this principle.
5. How are the axes placed in the *oblique system* of crystallisation? and by what names do you distinguish the two axes which are not vertical, and the horizontal prisms which are produced by modification in those directions?
6. Enumerate some of the irregularities of the surfaces of the faces of crystals.
7. Describe the principle of the *contact* and of the *reflecting Goniometer*.
8. What is meant by *simple* and by *double refraction*, and state what relation appears to exist between these phenomena and crystal-line form?
9. Mention some instances of *Isomorphism* in mineral substances, and of the difficulties arising hence, in carrying out a strict scientific arrangement.
10. What are the leading principles of the arrangement adopted by Werner, by Mohs, and by Berzelius?
11. Describe the chief characteristics and localities of the *Diamond*, of *Graphite*, and *Anthracite*.
12. What is the crystalline system, and what the ordinary form of *Quartz*? and enumerate the varieties generally known under other names.
13. Describe the external and chemical characters of *Hornblende* and of *Augite*, pointing out wherein they differ importantly, and with what classes of rock they are associated.
14. What is the generally occurring form and the chemical constitution of the gems termed *Emerald*, *Garnet*, *Amethyst*, *Topaz*, and *Zircon* or *Hyacinth*?
15. What are the chief characteristics of the ores of Manganese called *Pyrolusite*, *Manganite*, *Braunite*, *Hausmannite*, and *Psilomelane*?

16. Describe four of the most important species containing Lead. Draw a crystalline form from the Cubical System, showing a combination of faces of the Cube and Octohedron; and from the Rhombohedral System, showing the combination of faces of the pyramid, prism, and terminal plane; distinguish the faces by their proper symbols, and state which of the species described assume such forms.
17. What are the minerals most valued as ores of Copper? In what systems do they crystallize, and what are their chief constituents? By what methods is the presence of this metal in its ores readily detected?
18. Which of the precious metals occur in a native state, and under what circumstances?
19. Mention the Crystalline System and form of the models of crystals placed on the table.
20. Give the name and chief characteristics of the minerals lettered A, B, C, D, E, F, G, H, I, K.

WARINGTON W. SMYTH.

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LIST OF GEOLOGICAL MAPS AND SECTIONS,

PUBLISHED BY MESSRS. LONGMAN & Co. FOR HER MAJESTY'S STATIONERY OFFICE.

THESE Maps consist of the Maps of the Ordnance Survey, Geologically Surveyed and Coloured by the Geological Survey of Great Britain, by the Authority of Her Majesty's Government, under the Superintendence of Sir HENRY DE LA BECHE, Director-General of the Geological Surveys of the United Kingdom. The various Formations are distinctly traced and coloured in all their Geological Subdivisions.]

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VALUE OF AN EXTENDED KNOWLEDGE
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AND THE
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BY

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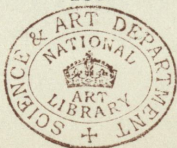
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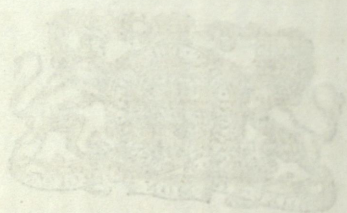
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Πολλὰ τέχναι ἐν ἀνθρώποις εἰσὶν ἐκ τῶν ἐμπειριῶν ἐμπέλως εὐρη-
μέναι· ἐμπειρία μὲν γὰρ ποιεῖ τὸν αἰῶνα ἡμῶν πορεύεσθαι κατὰ τέχνην,
ἀπειρία δὲ κατὰ τύχην.—*Plat. Gorg. (Polus.)*

There are many arts among mankind which have been invented by the experienced, through the means of experience: for whilst experience causes our age to advance by the principles of art, a want of it leaves us dependent on chance.

HAVING been honoured with the charge of opening in this Institution a course of instruction on Mineralogy and on Mining, I deem it desirable in the outset to define the limits of these distinct although kindred subjects, and to point out the directions in which they dovetail into the other branches of applied science as treated by my colleagues. The technical character of the education to be imparted here will be the beacon which I shall endeavour to keep in view, that I may avoid being drifted by the current of thought too far into the wide expanse of general considerations, where in connexion with those studies so much that is beautiful and useful in ordinary life has already been acquired, and so much still remains to be discovered; but where in the meanwhile we might wander wide of the desired path. This discourse will therefore deal almost entirely with matters of practical application; and a number of examples which have been brought under my own observation during a few years past will be adduced in support of the proposition—that *an extended knowledge of mineralogy and the processes of mining are essential to those interested or engaged in mines.*

In the commencement of an inquiry into the infinite variety of objects surrounding us in the natural world, presented, it would appear, for the purpose of inducing the most attractive and holy exercise of our observing and reasoning powers, it is obvious that three principal assemblages are to be discrimi-

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nated. These divisions are the animal and vegetable kingdoms, characterized by organic structure, and the wondrous phenomena of life; and the inorganic or mineral kingdom, comprising that far greater proportion of the materials of the planet in which no traces of organic structure are observable. This last assemblage of objects has been generally understood to form the province of mineralogy, which thus in its most extended sense would include all the æriform and gaseous bodies occurring in nature, and could hardly venture to exclude the multifarious substances produced under similar chemical laws by the agency of man.

But since, amid the daily increasing accumulation of new and unexpected combinations, the domain of the inorganic kingdom appears unlimited, and many of its phenomena must be investigated by special departments of science, it becomes necessary to draw a boundary line around that portion of it which is to be embraced in modern mineralogy; and where we can find no logical distinction between the actual products of similar bodies and similar laws, as seen in nature or in art, we must, for the sake of convenience and utility, rest our criterion of separation upon the different conditions of their origin.

Under this point of view mineralogy has for its object the consideration of the natural inorganic materials of our globe, fluid and solid; the physical phenomena which they present, their chemical constitution, their modes of occurrence, the methods by which they are distinguishable from each other, their classification, and the uses to which they may be made subservient.

Now it is evident that as the characters of minerals are dependent partly on their form, partly on their chemical and partly on their physical properties, mineralogy must be based upon geometry, chemistry, and natural philosophy; and the history of the science affords the best proof that no branch of knowledge can rise towards perfection till the conterminous sciences have, after due cultivation, been brought forward to aid in its development. The student should therefore previously acquire a certain acquaintance with these auxiliaries; and it is for this reason that the lectures on chemistry and physics have

been so arranged as to precede the more compound subjects on which we are now about to commence.

It may at first sight appear trivial and unnecessary to insist on the definition and objects of mineralogy; but, in addition to the importance of a clear understanding of the purport of any branch of education, there are in the present case special reasons for adopting such a course. This science has in Britain, for many years past, been cultivated by so small a number of investigators, that by the public at large it has been almost lost sight of, and is not unfrequently confounded with chemistry, geology, or metallurgy. Nay, there are not wanting among scientific men those who assert, that as a mere department of chemistry it can hold no independent place, nor offer a foundation for a special course of study. The above definition, however, may aid in fixing its true position, and will show, that whilst we contend with such opinions on the one hand, we would oppose on the other the vain struggles of those who have endeavoured to disconnect the science from that chemical aid which has so much advanced its progress and heightened its interest.

The prime and grand interest attached to our studies of the products of the earth is to be found in the fact that the mineral properties of different lands, in conjunction with their geographical features, have determined the distribution, the physical and social character, and the well-being of the various races of man. Whether we examine the vestiges left by the peoples of gray antiquity, or study the modifications produced in branches of the same race located in regions of different aspect, or inquire into the origin of the chief seats of modern civilization, we shall be assured that most of these phenomena are dependent immediately, or through the medium of vegetation, on mineral produce, and the particular conditions under which it can be made available to human convenience.

In the remains of ancient Egypt we learn how a stupendous architecture arose by the aid of the soft yet massive sandstones piled by nature on the banks of the Nile, and how monolith statues and obelisks were suggested by the presence of a syenite capable of taking a high polish, and admitting of the sharpest intaglio tooling. In Attica the marble of Pentelicus and the

silver of Laurion combined to develop that high state of art which, exemplified in the Parthenon and the sculptures of Phidias, has never since been equalled; whilst the abrupt limestone ravines of Lycia and Arabia Petraea gave rise to a description of architecture peculiar to itself.

As examples of the second point, call to mind the different occupation and character of the dwellers in the Spanish peninsula,—the active mining and mercantile population of Galicia, Asturia, and the Basques on one hand, the indolent Castilian and Portuguese on the other.* Or compare the torpid millions of the Slavic race in the plains of Russia with their industrious relatives and co-religionists in Servia and Bulgaria.†

Lastly, in furtherance of the third inquiry, we need only to examine the beautiful population map of the British Islands by Petermann, which shows at a glance that besides the conditions requisite for the purposes of shipping, it is coal and iron and lead and copper that mainly influence the increase of our towns. Nor can we omit to refer to the amazing process by which the discovery of gold is at this day pouring a new tide of population over parts of Siberia, to Western America, and to the Antipodes.‡

Such general views are, however, somewhat foreign to my purpose; for the main question which lies before me is the importance of mineralogical knowledge to those engaged in technical avocations. Enormous as is the interest at stake in connexion with this science, it is obvious that a more or less profound acquaintance with its facts must be productive of considerable differences in the progressive development of the national wealth. It is surely patent to all that the miner ought to be thoroughly acquainted with the nature of those substances

* Le Play, *Ann. des Mines*, 1834.

† C. Weerth, "Die Entwicklung der Menschenrassen durch Einwirkungen von aussen." Lemgo, 1842.

‡ Virlet, "Coup d'œil statistique sur la Metallurgie dans ses Rapports avec l'Industrie, la Civilisation, et la Richesse des Peuples." 1837. Ami Boué, "Der ganze Zweck und der hohe Nutzen der Geologie." Wien, 1851.

which it is his daily task to seek in the recesses of the earth, as well as with those which exert a favourable or a pernicious influence either on the abundance or quality of the objects of his search. No less should he be prepared to recognise those which, although unusual in the spot where he has commenced his career, may be thrown in his way either in another part of the same vein, or in neighbouring veins of the same district, or even in other lands, to which, by the varying demands for mining skill, he may so probably at some time be transplanted.

Supposing even that our miner had perfected himself in a science requiring far more close application to books and in-door study; supposing that he were an expert chemist, I venture to assert, that although in many cases highly serviceable to him, this rare acquisition would not make amends for an ignorance of mineralogy. Were he, each time that he required to know the nature of a substance, obliged to enter upon its chemical analysis, his days and years would be passed in endless labours often repeated and sometimes fruitless. If we concede that after twice or thrice analysing the same ore, for example, he were to recognise it the fourth time by some less laborious test, we allow, in other words, that he has acquired a mineralogical knowledge of that single substance: and thus we arrive at the conclusion, that the methods of mineralogy are those which a man must employ, if, in relation to the natural inorganic bodies, he desire to reap the advantages offered him by previous investigations.

There exists, it is true, in practice a source of difficulty which has probably gone far to prevent the spread of our science. Whilst many of the more abundant and valuable productions of the mineral kingdom are met with in such a state of impurity from mechanical aggregation and admixtures, that the particular minerals of which they are composed are not separable by physical means, others occur only in an amorphous or irregularly shaped condition. Now scientific mineralogy bases its descriptions on the most perfect individuals, or crystals, of each species, bodies which are comparatively rare; and treats with but little respect those which are never crystallised, and of which the distinguishing characters are less definite. It stands to reason that in an Institution of a practical tendency the strictness of

such rules must be relaxed, and that greater weight must be attached to those substances, chemically impure though they may be, which are abundantly yielded by our mines and quarries, and yet scarcely constitute true mineralogical species.

We shall thus, for example, study the characters of the pure carbonate of iron in the crystals occasionally lining the cavities of our lodes, in the masses which exert so powerful an influence on the industry of Nassau and the Austrian Alps, and again in those indefinite mixtures which as nodules and continuous beds have, from their geological position and abundance, contributed in a high degree to raise Great Britain to her present pinnacle of manufacturing power.

But the cause of such a preference in mineralogical works is at once evident, on comparison of the objects described with those of the other classificatory sciences.

In the animal and vegetable kingdoms the naturalist traces, in successive groups of animals and plants, a descending scale of lower and lower organization, till at last, in the most rudimentary forms of life, individuality is lost in an assemblage; yet down to this point each species presents none but forms complete in themselves, and almost unvarying. In the mineral kingdom, on the other hand, we are obliged to seek out for description the most perfect specimen, because it is not a succession of species, but the same species which offers a never-ending diversity of aspect. The mineral species may indeed occur in every state of development, from the symmetrical crystal, composed of definite constituents, passing through every grade of incompleteness of form or admixture with foreign substances, till we reach the lowest step of the scale, where the individual is so merged in the mass that form is destroyed, and the other characteristics are no longer discernible to the sense. How striking is the parallel in human societies, where the development of mind and resources unmistakeably accompanies such arrangements as lead to the self-reliance and importance of the individual, whilst as surely the crippled freedom of action caused by merging individuality in the crowd is attended by deterioration and destruction of all healthful prominences of character!

But besides the miner, there are hundreds and thousands

amongst us whose pursuits, bearing on the practical purposes of life, render a knowledge of mineralogy an element of success. The geologist, the engineer, and the architect must have recourse to mineralogy to gain acquaintance with many of the materials which they employ; nor, even if they possessed unlimited time and means for the acquisition of chemical analyses, could they afford to overlook the physical properties which are often chiefly instrumental in fitting those substances to their several applications. The agriculturist, if he wish to modify and improve the condition of his soils, must become familiar with the appearance and qualities of the marls, limestone, gypsum, phosphorite, and other minerals, which are now beginning to exert a remarkable influence on his art. The antiquary, without a knowledge of the stones from which the ancient inhabitants of the earth sculptured their idols, reared their temples, or fashioned their rude implements, and of the ores from which they produced their metals and alloys, can draw no sound conclusions as to the comparative civilisation of distant epochs, nor guard himself from the blunders consequent on faulty observation or crude description. Who, again, that is not insensible to the varied beauties of the brilliant gem, would hesitate to prefer to determine its nature by the methods of mineralogy instead of entrusting it to the chemist, who, with ruthless hand and devouring acids, must destroy its substance ere he can pronounce upon its character?

Other and numerous mineral productions there are for a decision on whose value we are dependent on the aid of analysis. Among the irregularly mingled bodies to which I have before alluded are many which, like the iron ores lately discovered in the oolitic formation, can only be determined as to their importance by accurate assay. Few among the crowds who at the late Industrial Exhibition swept by the series of iron ores brought together from all parts of Britain by Mr. Blackwell, could have prophesied that the collection of half a dozen of those sombre stones would give rise within a few months to an active industry, which bids fair to develope a new phase in the gigantic phenomenon of the British iron trade. An example, this, of the mutual dependence and assistance of three sister sciences, where geological reasoning had to point out the tract in which

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a given formation was to be found, mineralogical observation to discover the actual deposit, and chemical analysis to determine the value of the ore.

The mining districts of Great Britain are so utterly destitute of the means of mineralogical education, whether in schools or suitable collections, that it need be no source of wonder to find the most intelligent miner acquainted only with some two or three of the substances, which in the routine of his employment have been brought prominently before him, and often neglecting others from ignorance of their nature, or dangerously confounding things which are totally distinct from each other. It is matter of history that the copper ores of Cornwall were recognised as useful only at a comparatively late date, the miners having concentrated all their attention upon the tin with which that county was so plentifully supplied. More wonderful does it appear, that even at the commencement of the last century, when the yellow ore or pyrites had been long appreciated, the far more valuable redruthite, or sulphide of copper, was thrown as worthless rubbish over the cliffs of St. Just into the Atlantic; and Pryce informs us, that "many thousand pounds worth of the rich black ore, or oxide of copper, was washed into the rivers and discharged into the North Sea from the old Pool mine."*

These might be considered as the errors of a past age, but we may recollect that they occurred at a time when the value of the same substances was understood in other countries; and by mere accidental rencontres similar cases are still not unfrequently brought to our notice.

During a visit, three or four years since, to a mine which was supported chiefly by raising blende, the sulphide of zinc, my attention was attracted by a lump of white mineral lying on the window-sill of the office, a single glance at which was sufficient for recognition; and I put to the agent a few questions regarding its nature and occurrence. He replied that it was nothing but "spar", and that in working a particular part of the lode they had met with many tons of it, which, however, had been all, except this accidentally preserved specimen, irretrievably mixed with the rubbish heaps. The surprise of my informant

* Pryce, *Mineralogia Cornubiensis*, 1778.

was not small, when he learned that the so-called "spar", confounded by him with quartz, was calamine, an ore containing in its pure state above 60 per cent. of oxide of zinc. Not to leave the same metal and its ores, which put on a great variety of characters, I have known zinc blende taken for lead ore, and honoured with the erection of a smelting furnace, when, to the chagrin of the manager, the volatile metal flew away up the chimney, leaving only disappointment and loss behind. Again, from a faint resemblance which some of the varieties bear to certain iron ores, a resemblance which would at once disappear before accurate observation, a considerable quantity was bought, not long since, by one of the greatest iron-masters in this country. It was carried to the furnaces, duly mingled with fuel and flux, and after a strenuous effort had been made to get it to yield iron, it all, as the proprietor naïvely remarked, "went off in smoke."

Blunders of this kind are more excusable when made in regard to some of the minerals of comparatively rare occurrence. An active agent of my acquaintance, a man of high character, was requested by a couple of his friends, who gave themselves credit for uncommon sagacity, to join them in forming a company to work a deposit of an unusual ore which they had lately found. Already they had referred it, for corroboration of their opinion, to a person at Birmingham styling himself a mineral chemist, whose report set forth that the specimen shown him was, as the others had suspected, an ore of molybdenum, and that it was worth 8*l.* per ton. This was sufficient to induce the agent to join the discoverers in a journey to the place in question, and at the head of a remote valley, embosomed among the rugged hills of Cambria, he was gratified with the view of such a mass of the same substance that it was evident that thousands of tons might be quarried at a mere nominal price. Specimens were broken, the party returned to consider the preliminaries of their adventure, and it was agreed that the mineral corresponded pretty nearly with the description of sulphuret of molybdenum in some book, which was at hand. Still, the more cautious manager feared that the prospect was too bright to be real, and without consulting the others, expended a fee in sending for a good analysis to a scientific chemist in London. The result was, that the substance in question proved to be a shining, black,

slate-clay, not applicable to any use, except perhaps to make bricks.

Within a gunshot of the place where the above-mentioned agent related this anecdote, the appearance of some rather ferruginous slate rock attracted the attention of a party of credulous speculators, who believing they had discovered a rich iron ore, actually built a blast furnace, erected the necessary machinery, and continued for some time to carry out their vain attempt, deluded by the fraudulent practices of the workmen. As might, however, have been predicted, the undertaking soon ended in abandonment and ruin.

In other mining districts I have known persons, who although possessed of great general intelligence, have collected blue stones (generally ores of copper) for cobalt, ignorant of the fact that none of the natural combinations of this valuable metal possess a blue colour.

The sulphate of baryta has for a few years past borne a certain value for manufacturing purposes; and an instance was brought to my notice, where a ship-load of what was supposed to be this mineral was obtained by surreptitious means, and sent from a distant part of the country to London. But the biter was bit, for his observation was faulty, and his cargo, proving to be calcareous spar, was worthless. It would tire out your patience to enumerate the cases in which mica or iron pyrites have been mistaken for gold. From the anxious country gentleman in our own land, to the disappointed Californian gold seeker, and to the solemn Turkish Bey mysteriously unwrapping from many a folded rag the specimen of his expected wealth, such victims of mineralogical ignorance are frequently presented to those whose pursuits bring them into a position for advising on similar points.

But there is another and a wider field far more important than the correction of isolated mistakes, in which mineralogical research has yet to be largely employed, and in which the connexion of this subject with mining is no less grave than intimate. The principles by which the accumulation of ore in lodes or metalliferous veins has been regulated are to this day so enveloped in mystery, that the prosecution of mining enterprizes is almost as much a matter of chance as it was with our forefathers

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three centuries ago. Nor can we wonder that this should be the case, when we regard the peculiar difficulties by which the subject is beset. Not only is the progress of the operations so slow that the observation of one set of phenomena may extend over many years, but the examination of some points, unless made at the time of first opening, is precluded by the discolourations of water and powder smoke, or by the means adopted to secure the works. Then, according to the conditions under which the lode is placed, a combination of problems, geological, physical, and chemical, are presented for solution, and the thoughtful mining agent, left to consider them only by the light of a partial experience and natural shrewdness, is commonly led to see them through a peculiar medium, and to fall into the numerous errors resulting from unsound premises. Copious stores of knowledge have, it is true, been acquired by many of the captains and tributers in Cornwall and elsewhere; but besides the difficulty, according to the various views of individuals, in collating them, they have generally, from want of early educational opportunity, been accumulated upon an unsafe basis; and finally, the experiences perish with the men, leaving society no richer for their acquisition.

Nowhere is there more room than in the study of this subject for accurate mineralogical observation,—nowhere is the prize offered more inviting; for the resolution of some of these questions must tend to acquaint us with the probability of finding remunerative ores in certain directions, either in depth or on the course of the lodes, and must, therefore, be instrumental in discovering untold sources of wealth. Nor need we despair, when we remember the confused state of all the natural sciences little more than a hundred years since, that at some future day a more systematic cultivation, by rigorous induction, founded on close observation, will clear away the weeds, and cover with plenteous crops this hitherto barren field.

We are thus naturally led, by the contemplation of the objects to be sought for, to the second part of our subject, the Art of Mining: and here it will be necessary to dwell at greater length on the character of the studies which it is desired to embrace, inasmuch as no course of instruction in them has yet

been attempted in this country; and, strange to say, not a single book exists in the English language in which they are comprehensively treated. Among the Germans many excellent works on mining have appeared from time to time during the last three centuries; and even in France, a country comparatively so poor in mineral productions, treatises have been published, in which many of the divisions of the subject have been skilfully discussed, whilst the periodical literature of both those nations is rich in detailed descriptions of the natural phenomena and the working processes of mines in all parts of Europe. Nor are we indebted to the Russians, whose well-educated officers of mining engineers, sent at the public expense to investigate various mineral regions of the continent, have carried back with them a treasure of valuable information, which has been in a great degree instrumental in advancing, to a high grade of perfection, the mining and metallurgical operations of the Ural and of Siberia. In Britain, however, we have little else than two or three treatises on the working of coal, and a few isolated papers on other parts of the subject; and hence it will be needful, in a series of Lectures, to depend in great part on personal experience, and to indicate, in exceptional cases, the sources whence a knowledge of details may be obtained.

But it would be an injustice to the many thinking and enterprising spirits among our British miners not to express our admiration for the skill and ingenuity which they have brought to bear on particular portions of their art. Surrounded by difficulties and dangers, they have won enduring triumphs; and in some of their applications have, by the force of persevering industry, advanced their experience with such rapid steps, that science has been glad to follow in their wake, and reap new facts to aid her further progress.

The first great feature which strikes the attention in approaching this subject is the enormous value of the mineral productions of Great Britain, amounting, as has already been stated by our honoured Director in Chief, to the sum of 24,000,000*l.* annually in the rough state. So bountifully, indeed, has our country been enriched by Providence with these sources of

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wealth, and in a degree so much higher than any other region in Europe, that it need excite no surprise if those natural gifts which even aroused the industry of the early Britons, and excited the cupidity of their Roman conquerors, yield at the present day an amount of riches far greater than those produced by any other nation. Let us, then, consider the great population supported directly by the extraction of these minerals, and indirectly by their application to the arts,—the maintenance of hundreds of thousands of men by these not inexhaustible stores,—and the entire dependence of our whole manufacturing and commercial system on the supply of fossil fuel; and we cannot fail to arrive at the conviction, that in exercising the stewardship of such gifts of Heaven, the nation has a high and responsible duty to perform, that waste and improvidence are a national sin, and that it behoves all who are in any way connected with the working of our mines to lend their best endeavours to the perfecting of the most economical and efficacious means of rendering all the products of our mines available to the uses of mankind.

It is not pretended that by any plan of education in an Institution of this kind, it is possible to make a miner, or in other words, to prepare a man for taking charge of a mine as soon as he has left our walls: not more reasonably should we expect that a lad drilled in the classes of a naval college were at once metamorphosed into a sailor, fitted at once to take command of a ship. Yet surely no one will deny, that if in that school he has learnt to box the compass, to knot and splice, if he has worked out problems in navigation on sound mathematical principles, if he has been taught by descriptions how to handle a vessel at anchor in a tideway, or on a lee-shore, he will be infinitely more ready to take advantage of circumstances, and to make rapid progress, than if he had been sent on board unknowing of these things and their principles. No "royal road" to learning, no legerdmain of "cramming," can make amends for the want of time and pains bestowed on the acquisition of practice; and as with the seaman so should it be with the miner.

By description, by drawings, and models, it will be our

endeavour to make the student familiar with the chief phases of the operations practised in various regions, and under different conditions. He will have, each year, the opportunity of closely inspecting the mineral features and particular mining processes of the districts under examination by the Geological Survey; and, when furnished with this preliminary knowledge, will, I doubt not, pass to his sphere of probation better qualified to observe and to compare; whilst the practical experience which he must afterwards acquire will be superadded to what he has already benefited from the labours of others.

Before we proceed to examine farther into the general question of the importance of endeavouring to establish in Britain a system of technical education for this department, let us consider the definition and principal heads of the subject before us; and, whilst so engaged, let us take an instance from each division, illustrative of the gain to be derived from an extended acquaintance with the modes of treating it.

The art of mining comprehends all the processes whereby the useful minerals are obtained from their natural localities beneath the surface of the earth, and the subsequent operations by which many of them must be prepared for the purposes of the metallurgist.

In the first place, among these processes must be mentioned, the search for localities in which we may reasonably hope to meet with the minerals occurring either in beds or lodes. It is obvious that a combination of geological and mineralogical knowledge is requisite for success, and that a mere empirical tact obtained in a given district may lead to fatal mistakes in another. Amid the phenomena of the lodes, their frequent heaves and dislocations, and their different appearance when bounded by different rocks, call for close attention; and although from lack of sufficient and well recorded observation, the principles upon which a criterion should be founded are far from fixed, we often find that a superior degree of general experience has been rewarded by success, when mere unintelligent working had been completely foiled.

Among the methods of proving the existence of useful deposits, none has yielded greater results, or is more capable of

extended application than the art of boring. For ascertaining the position of coal-seams, and for obtaining a supply of water, bore-holes are frequently sunk in many parts of the country. But we have yet, by a comparison of the practice of different countries, and the adoption of a more economical mode of sinking, where need be, to greater depths, to increase their sphere of utility. At Neusalzwerk, near Minden, a bore-hole has lately been pierced through the trias formations, to the depth of 2,300 feet, for brine springs; and another, at Mondorf, in Luxembourg, to near 2,400 feet, which, though unsuccessful in discovering salt, has supplied a spring of above 21 cubic feet per minute. At these and various bore-holes of less depth in Germany and France, a variety of apparatus has been employed, a complete study in itself, much of which has been serviceable in greatly reducing the time and cost of such operations. We may instance the ingenious instruments of M. Degousée, the "free-falling" cutter of Herr Kind, and the hollow iron rods of Von Ceynhausen, as a few of those which are well worthy of attention for the good service rendered in the execution of great works. Again, we know far too little of the routine of the Chinese well-borers, who have succeeded, according to the detailed statements of Father Imbert, in attaining the extraordinary depth of 3,000 feet, by their simple and inexpensive apparatus of rope-boring, an example which has been successfully imitated in the chalk districts of France.

The next division of importance embraces the tools used in mining. One of the greatest advantages which we enjoy over our forefathers is the use of gunpowder in rending a path through the harder rocks, which they with enduring and patient labour were obliged to cut away with hammer and wedge. But the implements employed in various districts differ not only in form and weight, but in their material and useful effect. Let me only allude to one point: in scarcely any of our mines, whether in the north or south, has it been attempted to use borers of steel; iron is almost universally, with us as in most parts of the continent, the material of which the shank of the borer is composed. Yet in Saxony, for many years past, as also in Derbyshire, and at Ecton, the work has been advantageously

carried on with borers of steel alone. Accurate experiments made and recorded at Eschweiler, and at Mannsfeld in Prussian Saxony, have been attended with favourable results; and Mr. Rogers of the Abercarn Collieries has succeeded in proving, whilst sinking a large shaft in hard rock, the value of steel tools, a set of samples of which were placed in the Great Exhibition, and afterwards presented to this Museum. Although the suitable tempering of cast steel is attended with some difficulty to the inexperienced, the following reasons for its preference to the ordinary material have been established, viz., the great saving in wear and tear; the reduction of original outlay, since the stock of steel borers may be smaller than that of iron in a lower ratio than that borne by the price of iron to steel; the diminution of smith's costs for sharpening, and of time lost by boring with a blunted edge, and the greater convenience of carriage in and out of the mine. Farther, the superior compactness of the material transmits the force of a blow more efficaciously to the required point, a fact corroborated by the observation that an iron borer will cut less ground with the same number of blows when new than after being for some time in use; And it need hardly to be added, that in the questions of time, material, and cost, connected with the breaking of ground, we touch on some of the most important elements of economy in mining.

I will not detain you with an enumeration of the points to be dwelt upon in the form of the excavations by which we enter into the earth, whether by the driving of levels or the sinking of shafts under different circumstances; nor, from among the modes of securing them by timbering, masonry, or ironwork, shall I do more than bring to your notice one ingenious application of physical science to these purposes. It is well known that the sinking of a shaft through loose sand or watery rock often besets with great and sometimes with insurmountable obstacles the approach to the useful minerals which lie in firm ground below. On the banks of the Loire repeated efforts to reach the coal measures through a thick bed of alluvial sand had failed, overcome by the great influx of water and loose material; when M. Triger bethought him that the simplest

mode of vanquishing the difficulty was to dam back the water, to employ a constant resisting force which might be maintained at small expense, in place of a moving power of enormous cost. It was, in fact, to pump into the iron cylinder which formed his shaft such an amount of air that the pressure on the bottom from within should be equal to the pressure from without; and the water was thus prevented from rising above a given height. Placing a cover on the cylinder, through which two pipes are inserted, one conveying the compressed air into it, the other dipping into the watery stratum, he found a stream of water and sand poured through the latter whenever it was unable to escape rapidly enough elsewhere. Then, in order that the men might enter upon or leave their working place without disturbing the equilibrium of the forces, he applied the principle of the canal lock, fitting an upper chamber in his shaft, where, when the upper door was closed and the lower one opened, all was filled with the compressed air; when the lower one was closed and the upper opened, the air-lock was relieved from its superabundant air, and men or materials might be introduced. Pages would be filled with the details of the difficulties met and overcome, and of the successful adoption of the principle in the sinking of larger and deeper shafts; suffice it to say, that M. Triger succeeded, surrounded by water, in joining his cylinder to the solid rock at a depth of 82 feet from the surface, having proved that human life could be supported, and work done, for many hours together under a pressure of $3\frac{1}{2}$ atmospheres. His procedure is marked by manifold advantages, and admits of various applications;—witness the removal of rocks in the harbour of Croisie, on dry ground, whatever the state of the tide. Verily, if Canute had possessed a Triger among his courtiers, he might, to better purpose, have defied the rising flood to touch his royal foot!

We shall be unable here to glance even rapidly over the many systems devised for working out the minerals attained by the foregoing operations: let us only scan an isolated case. The magnificent seam called the “thick coal” of Dudley has been worked throughout the entire field on a principle which by taking the whole height, 30 feet, at one time, has been

attended with such danger as to cause almost weekly some frightful and fatal accidents, and to exercise morally a pernicious influence on the character of the colliers; whilst it has necessitated the leaving of so large a proportion in "pillars" and "ribs", that only from 11,000 to 15,000 tons of coal have been obtained out of 40,000 contained in the acre. Here then is a loss to the national wealth of useful life, and of about two thirds of the finest fossil fuel in Britain, the money value of which would amount to many millions. Yet for twenty years past, in that very district, one group of pits has been worked on a system by which the coal is taken in two successive stages, where the men work in comparative safety, and where, instead of 11,000 or 15,000, 26,000 tons are realised per acre, although the seam is there of less than its average thickness. Consider only for one moment the beneficial effects of improved means of extracting the coal from our mines: it is supposed that the total quantity annually brought into use amounts to above 30 millions of tons; and if an economy of but threepence per ton were effected, by reducing friction, ineffective labour, or other sources of wasted power, a sum of nearly 400,000*l.* per annum would be saved to the country.

We must omit to speak of the modes of transport along the underground roads, of raising the minerals to the surface, and of pumping the subterraneous water, accomplished by an amazing variety of apparatus and machines. Nor can we dwell upon that important subject of ventilation, to which our attention is so often and forcibly called by the fearful catastrophes occurring in our mines from its absence or mismanagement. I would only call attention to the rude method of dispersing noxious gases figured by Agricola 300 years ago, and in some of our districts still adopted, under the term of "brushing out the sulphur," as the only means of rendering a place safe for the men to work in. But although even at that early day more refined processes had been introduced, as evinced by his description of the ventilating fans, let us compare all those puny means, and the efficiency of ventilation in the great bulk of our collieries with the skilfully applied and fiercely blazing furnaces of some of the great northern mines, where a current of 150,000, or in

one case near 200,000 cubic feet of air in one minute are circulated through the devious passages, and rush to the upcast shaft with the velocity of a hurricane.

Nearly related to this division, as regards the question of humanity, is the true construction and the preservation of mining plans. Take an instance in which the loss of 100 lives may ensue from the ignorance of a physical fact. Those familiar with the mining districts are well aware that the great majority of their maps are laid down without any reference to the phenomenon of magnetic variation. If, then, a colliery be in operation on the dip of old workings filled with water, the tapping of which would be death to all employed in the pit, and the maps had been constructed some years previously with respect to the magnetic meridian alone, the variation may in the mean while have so far changed that the exploring drifts supposed by the manager to be going clear of the known danger may, in reality, lead him straight to destruction. The art of surveying is, however, too important and extensive to be included in the lectures on Mining, and will ultimately, we hope, form the subject of a separate course.

The last group of operations to be included is the dressing of ores, on the efficient conduct of which the success of many a mine may depend. Whilst the Schemnitz miner is able to work actual gold ores broken from great depths, which, besides a little lead, contain no more than one part of gold in 228,000 of stone,* and whilst the Russians wash in their stream-works sands containing only one part in half a million, we learn from description that the Californian and Australian are employing processes more rude than what they might have copied from the miners of three or four centuries since, and that (inasmuch as the poorer

* In 1841-2, when I passed some months among the mines of Hungary, much had been done and was still doing by my friends the late Oberstkammergraf von Svaiczzer and Mr. Rittinger, the Inspector of Stamp-works, for the improvement of the dressing of gold and silver ores; and the works at Antal and Illia, near Schemnitz, were well worthy of admiration for their scale and economy.

part can only be profitably worked in conjunction with the richer) they are actually losing for ever a large proportion of the riches showered by nature upon those lands.*

Such are, in few words, the processes which will form the substance of a course of instruction in the art of mining; and it need scarcely to be observed that a preparatory acquaintance with physics, geology, and practical mechanics is indispensably necessary. For this reason it is proposed that the Lectures on Mining shall be given to the students of the second year, already provided with the preliminary studies, some of which have been commenced; but in order to obviate misconstruction, it is proposed during the present season to deliver a concise course, intended simply as an outline of the subject, leaving the more detailed treatment for the ensuing year.

Amid the entire circle of the sciences we can hardly mention one which the accomplished miner may not at some time call to his aid, from the science of numbers, on which all his other knowledge should be based, up to astronomy, which may assist in the construction of his maps. We cannot, indeed, expect that many will become, like Humboldt, (who was educated, and for some time practised, as a miner,)[†] master in several sciences; but when we add to these the acquaintance with business routine and commercial questions which the manager of mining property ought to possess, is it not clear as the noon-day that for those who desire to excel in this profession a special education ought to be superadded to the training of our schools and colleges? And is it not equally clear that with so vast a field of investigation before him the intelligent inquirer must ever remain a student, whilst only the shallow pretender can affect to be

* "Le désordre administratif et l'ignorance profonde, qui jusqu'ici ont présidé à ces sauvages opérations techniques, nous font présenter combien les lavages des terrains aurifères doivent être imparfait dans la péninsule, combien d'or y est perdu pour les générations futures!"—*Humboldt, Letter to M. Fay.*

† Alexander Von Humboldt was a student at the mining academy of Freiberg, in Saxony, in 1791, with von Buch, Freiesleben, and other coryphæi of mineralogical and geological science.

the arbiter of the difficult problems which daily present themselves?

From the examples above adduced I trust that I shall be justified in asserting, that a communication of knowledge, whether of the principles or of the practices involved in mining, must be attended by great pecuniary gain to the country at large. We shall be met, in the outset, by the argument more suited to the Cape Boer or the Chinese than to the progressive Anglo-Saxon, that because our fathers have done very well without it we may easily dispense with any such innovation; and that the immense mineral production of Britain is the best proof that we need not to follow the example of nations unable, with all their schooling, to rival us in that respect. But let us not overlook the great natural advantages with which we have been favoured, nor forget, that although individual perseverance has done much, very much, among us, we must still depend for advancement in a great degree on the experience of others. In good truth "he that neglects the culture of ground naturally fertile is more shamefully culpable than he whose field would scarcely recompense his husbandry: and it is as rational to live in caves till our own hands have erected a palace, as to reject all knowledge of architecture which our understandings will not supply."*

Taking even the present state of our knowledge as a standard, let us balance the argument on such crucial questions as the following. Do cases occur in which mineral substances are neglected from ignorance of their nature? Is it true or not, that others are wasted and lost to the nation by the character of the present operations? Do not crowds of well-meaning adventurers rue their introduction to the mining schemes of impostors? Are not hundreds of human lives sacrificed to a want of precaution and prudence? Is not the condition of machinery and apparatus in a great part of the country very inferior to certain now existing models? Are there not numerous sources of wealth lying unemployed from the uncertainty consequent on a

* Johnson. Rambler, No. 154.

want of former records or present knowledge? No one, I am confident, acquainted practically with our mineral districts, will hesitate in replying, that in all these points great and salutary changes may be made, and that enlarged opportunities of learning accorded to the mine agents must produce their fruits in due season.

As for the miserable plea of ignorance, that the country cannot fail to prosper, in whatever degree her sons may squander the stores of nature deemed inexhaustible,—it but leads the mind back, through many centuries, to an instance of similar reckless boasting, followed by a warning fate. In the palmy days of Athens, when the silver mines of Laurion were vivifying art, commerce, and luxury, Xenophon asserted, in a formal treatise on the revenues of the state, that “whatever number of men had been employed in those silver mines, no diminution had been practically effected in the quantity of the ores;—that there was no limit to the productiveness of the veins, either in depth or in extension, and that their riches, in fine, were inexhaustible.”* Let any one contrast such assurances with the beggared state of the land ever since.

I would be far from strictly comparing the conditions of Attica or its people with our own; but we must bear in mind, that in all our mining districts the minerals are extracting at a fearful rate, and each year in an increasing ratio, and that after a certain lapse of time scarcity and increase of price must necessarily follow. In the meanwhile, we have numerous rivals in other and less favoured lands, doing their utmost to make up for natural disadvantages by fostering education and acquiring a sound knowledge of the principles on which they act. In this race they have often been checked by political troubles and peculiarities in their social relations; but, having so thoroughly secured each onward step as to be comparatively independent of

* Μαρτυρεῖ δὲ καὶ αὐτὸ, ὅτι, ἐργασμένων ἀνθρώπων ἐν τοῖς ἀργυρίοις ἐν τῷ παντὶ χρόνῳ ἀναριθμήτων, νῦν οὐδὲν διαφέρει τα ἀργύρια ἢ ἃ οἱ πρόγονοι ἡμῶν ὄντα ἐμνημόνευον αὐτά. . . . Οὔτε γὰρ βάθους πέρας οὔτε ὑπονόμων οἱ δρύττοντες εὐρίσκουσι.—*Xen. de Vect. c. iv.*

the fleeting skill of individuals, they nevertheless press forward again in the same path; and when the day comes that our preponderance in natural treasures is reduced to something nearer equality,—when deeper and thinner coal seams must be wrought, when poorer ores of the metals must be more highly prized, and when the products of our manufactures can only be brought into commerce at higher prices,—then must the star of England's prosperity decline, unless we keep our vantage ground by the superior skill and knowledge to which technical education must greatly contribute.

Thus far we have directed our attention almost exclusively to the material advantages, or, in other words, the pecuniary returns to be expected from the cultivation of these subjects. I have dwelt so long on such topics because the main object of the foundation of this course of instruction has reference to that point of view.

But I should ill appreciate the character of this audience, and do violence to my own feelings, were I not, in conclusion, to protest against that debasing spirit which would decry all branches of knowledge except those which are at once commercially profitable, and which would practically inculcate a belief that the acquisition of money is intended to be the great end and aim of human existence. Shall we, for their own sake, examine the works of the architect, the painter, or the poet, and analyze the rules upon which his art is founded, whilst we yet remain indifferent to any one department of the rich storehouse of nature, opened for man's inspection by the Author of all things?

Believe me, that the phenomena of mineralogy, and the principles which regulate them, are, though different in their kind, no less beautiful than those of animal and vegetable life; and they possess the additional source of interest, that they may guide us to the wider sphere of speculating rationally on the constitution of the orbs which roll with us through endless space.

With reason has a Turkish author* said, "Consecrate, O my

* Nabi Effendi, a counsellor of Sultan Mustapha III.

son, the aurora of thy reason to the study of the sciences; in the vicissitudes of life they are an infinite resource, they form the mind, they polish the understanding, they instruct man in his duties, they delight and amuse us in prosperity, they become our consolation in adversity." Indeed, to the student in his cabinet, no less than to the traveller through Alpine passes, or over regions explored by the skill of the miner, the study of minerals offers at the same time an attractive recreation, and an efficient method of disciplining the faculty of observation. The closer we investigate the principles on which their constitution and their physical properties depend, the more are we startled by new and convincing proofs that it is only the imperfection of our knowledge which as yet prevents us from seeing more than the glimmering outline of that harmony which pervades all the works of nature. The system of law, the νόμος ὁ πάντων βασιλεὺς of Pindar, working as surely in the particle which vanishes from our power of sight, as in the loftiest mountain mass, reveals itself with more distinctness the farther we advance; and although the difficulties of inquiry are heightened, so are its pleasures also increased by the ties of brotherhood, which springing hence unite our pursuits with the other natural sciences.

Nor let it be supposed that the details of mining are unproductive of advantage to any but the professional miner. Deep in the bowels of the earth the labour of generations has wrought out edifices no less worthy of admiration than those which the skill of the architect has reared upon her surface; and if, in the latter case, we esteem it desirable to learn so much of the principles of the art as may enable us to appreciate the design of the craftsman, so in the former shall we find in the magnitude of the operations, in the diversity of the natural appearances brought to light, and in the ingenuity of the processes adopted for the maintenance and extension of the works, a harvest of facts no less interesting than suggestive of farther inquiry.

Whatever may be the imperfection of the teacher of these subjects, there is in themselves so much that is exact, so much that is vast, so much, in fine, that is most worthy of man's highest powers, that we may hope, out of the number who will

enter with us on the curriculum, to see some few, at least, who will not stop short at that point whence they may obtain their worldly ends, but will persevere towards that goal of higher knowledge which has been, and always will be, the object of the noblest of mankind.

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ON

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KNOWLEDGE

TO THE

PRACTICAL METALLURGIST.

(BEING THE INTRODUCTORY LECTURE TO THE COURSE OF
METALLURGY, SESSION 1851—1852.)

BY

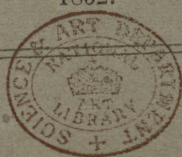
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MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied
to the Arts.

ON

THE IMPORTANCE OF SPECIAL SCIENTIFIC KNOWLEDGE

TO THE

PRACTICAL METALLURGIST.

(BEING THE INTRODUCTORY LECTURE TO THE COURSE OF
METALLURGY, SESSION 1851—1852.)

BY

JOHN PERCY, M.D., F.R.S.

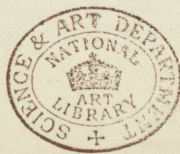


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MUSEUM OF PRACTICAL GEOLOGY

Examination & Report of Minerals and of Economic Geology
to the State

The subject which I have been requested to treat in this
report is a very important one in the history and geology
of the State. It is the subject of the **MINERALOGY**
of the State. I have been requested to treat of the
minerals which are found in the State, and of the
economic geology of the State.

The first part of the report is devoted to a description
of the minerals which are found in the State. I have
described the minerals which are found in the State, and
the economic geology of the State.

The second part of the report is devoted to a description
of the economic geology of the State. I have described
the economic geology of the State, and the minerals
which are found in the State.

The third part of the report is devoted to a description
of the minerals which are found in the State. I have
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the economic geology of the State, and the minerals
which are found in the State.

THE subject which I have been appointed to teach in this Institution is essentially practical in its character and relations. In the introductory discourse, which I am now about to deliver, I shall explain the nature and object of the instruction which I propose to impart, and point out what I conceive to be its advantages.

Metallurgy, as at present understood, is the art of extracting metals from their ores, and adapting them to various purposes of manufacture. This definition, however, is not rigidly exact, nor can I frame one in few words that is so.

The etymology of the word "metallurgy" would seem to imply a more extended meaning, and include all the arts in which metals are wrought into objects of utility or ornament; but this is not the meaning now attached to the word.

The metallurgist receives the ore from the miner freed as perfectly as possible by mechanical processes from foreign matter.

The knowledge of the principles of metallurgy is the science of metallurgy. But as the phenomena observed in metallurgical processes relate to physics and chemistry, and as mechanical appliances of various kinds are employed in these processes, it follows that chemistry, physics, and mechanics must be the foundation of the science of metallurgy. In order, therefore, that the student may with advantage enter upon the study of metallurgy, it is essential that he should possess a considerable amount of preliminary knowledge.

The history of metallurgy dates from remote antiquity; and, as Le Play correctly observes, "most of the fundamental phenomena of metallurgy were discovered and regularly applied to the wants of man before the physical sciences properly so called

existed.”* Metallurgy may, indeed, be said to have given birth to chemistry.

My colleagues having addressed you at some length on the aid which science may be expected to render to the manufacturing arts, it might appear superfluous that I should occupy your attention with the same subject. I shall, however, do so for two reasons:—first, because I shall be able to adduce from my own observation several striking cases in illustration of the advantage of the application of science to practical metallurgy; and, second, because the practice of metallurgy, so far as relates to magnitude of operation, having been developed to an unparalleled extent in this country in the absence of specific public instruction on the subject, it is necessary to justify the providing of such instruction at the present time.

As the word “science,” in relation to a manufacturing art, is often used by persons who seem to have no precise idea of it, I shall first adduce a simple illustration of its meaning. There is an ore of copper, composed of copper, iron, sulphur, and silica. When such an ore is subjected to a series of processes consisting of heating it with the access of air, melting, &c., copper is separated in the metallic state. The sum of these processes is termed the smelting of copper. Now in this operation of smelting various chemical changes take place; the sulphur combines with the oxygen of the air, and is evolved in a gaseous state; the iron also combines with the oxygen of the air to produce oxide of iron, which combines with the silica to form a slag, while the copper is separated in the metallic state. We have thus several facts, which are proved by chemical evidence. These facts may, when properly arranged, be said to constitute the scientific knowledge of copper-smelting; and that knowledge implies necessarily a knowledge of the chemical relations of copper, iron, sulphur, oxygen, and silica to each other. There are also many other facts connected with copper-smelting; but those which I have selected are sufficient for the present purpose of illustration.

* Le Play. Description des Procédés Metallurgiques employés dans le Pays de Galles pour la fabrication du Cuivre. Paris, 1848.

Now, the man who conducts the process of copper-smelting in ignorance of these facts has simply an empirical knowledge, in contra-distinction to a scientific knowledge, of the process.

That a scientific knowledge of the process may be important to the man who directs copper-smelting works would hardly seem to require an argument. It may, however, be objected, that the process is often satisfactorily conducted by men whose knowledge is purely empirical. Now the objection would have some weight if it were admitted either that the process is incapable of further improvement, or that the ores upon which such men are accustomed to operate were not liable to vary in composition. But such an admission would be a purely gratuitous assumption; and the ores do occasionally contain unexpected ingredients, which, in the event of precisely the same process of smelting being pursued, would tend in a very sensible degree to deteriorate the quality of the copper produced. Hence, ignorance of the presence of such ingredients on the part of the smelter may occasion pecuniary loss; and, in ignorance both of the causes which thus may injure the copper and of the scientific knowledge of the process of smelting, he is certainly not in the most favourable condition for devising an appropriate remedy. It is true that by a series of blind trials a suitable modification of the process might be stumbled upon; but it is equally true that with the aid of special scientific knowledge there is much more probability of arriving at a solution of the difficulty with far greater economy of time and money. The case which I have put is not imaginary, but real; nor is it, as I know from my own experience, a solitary one. When I treat of copper smelting I shall enter into detail upon this subject.

In support of the general proposition, that special scientific knowledge is important to those who direct metallurgical processes, I shall now present to your notice several cases, most of which I can myself substantiate.

A party purchased a large quantity of a particular ore, at the cost of many thousand pounds. Another party purchased at the same time a much larger quantity of the same ore, at the same price. To treat this ore profitably, special scientific knowledge was essential. The former party possessed that knowledge, and

gained thousands by his purchase ; but the latter had it not, and lost money.*

A manufacturer purchased some metallurgical works, and for certain miscellaneous articles on the premises, including a heap of waste product, gave only a very inconsiderable sum. Out of that heap, which in ignorance had been thrown aside as worthless, he realized sufficient to pay for the works, the price of which amounted to several thousand pounds.

An eminent copper-melter informed me, that his ancestor, in purchasing some old copper-works, obtained in value more copper from the furnace bottoms than the purchase-money. In this instance, perhaps, negligence might be ascribed to the seller, but in that last mentioned the error was the result of sheer ignorance.

In 1841 a patent was taken out for "certain improvements in the manufacture of iron and steel." The invention mainly consisted in soaking the pigs of iron in cold water previously to their introduction into the puddling furnace.†

Again : a short time ago a patent was obtained for plating certain metals and alloys with a particular metal, and a manufactory was erected at a considerable outlay to carry out the invention. It was alleged that the importance of the application consisted not only in the whiteness of the metal employed, but in the economy of the process. Now the metal in question was at that time at least thirty times dearer than tin, and was produced only in small quantity. But the inventor was sanguine, and assured me that an ore containing forty per cent. of it existed in abundance, whereas the fact is, that only a few ounces of such an ore have ever been discovered, of which specimens are rare even in mineralogical cabinets ; and the ores

* It would be impossible for me, without breach of confidence, to enter into more specific details in the narration of this and the following instances.

† Patent granted to Wm. Turner Green and James Gregory, of West Bromwich, Staffordshire, for certain improvements in the manufacture of iron and steel, May 14, 1841. A report of this patent has not been published, but the original document may be seen at the Enrolment Office.

which contain it and occur abundantly in nature do not yield more than two or three per cent. of it. This case, it is true, may be regarded rather as indicative of ignorance of mineralogy, than of metallurgy; still it may be appropriately introduced under the present head, as an argument for the necessity of the diffusion of accurate scientific knowledge amongst metallurgists. The inventor speculated on the probability of a demand creating an adequate supply of the metal at a comparatively small cost; but special scientific knowledge would at least have prevented the precipitate investment of capital on such a speculation.

Facts such as I have just mentioned should be a warning to the numerous class of inventors in this country, whose naturally sanguine temperament is liable to disturb the exercise of their judgment. The published records of patented inventions, indeed, furnish a striking commentary on the proposition before us. The diffusion of the scientific knowledge relating to metallurgy would often prevent the reckless expenditure of money on worthless patents.

Very striking instances in support of the same proposition may be derived from the important branch of metallurgy termed "assaying," or the art of determining the quantity of metal contained in its ores, alloys, or certain other compounds. Without a correct assay, it is obvious there can be no certain knowledge of the value of an ore; and without that knowledge, the purchase of an ore by the smelter is merely a speculation. Now by great practice upon some particular class of ores, the merely practical assayer may arrive at accurate results, and yet be entirely ignorant of the science of his art, or, in other words, of the chemical properties and relations of the elements upon which he operates. But if, as I have already mentioned in the case of the copper-smelter, he should meet with an ore containing foreign and unexpected ingredients, which interfere with the accuracy of the method he had been accustomed to practise, he would not, from his want of scientific knowledge, be able to surmount the difficulty, and would consequently, from his necessarily erroneous result, seriously mislead the smelter respecting the value of an ore. Or he might equally mislead the seller who relies upon his judgment, either by underestimating the quantity

of the particular constituent which he seeks to determine by his array, or by overlooking another constituent, it may be of great value. In illustration of errors of this kind, I have selected the following instances.

An ore of cobalt from North America was assayed, and alleged to contain twenty per cent. of oxide of cobalt, which at the time was worth about 30s. a pound. The assayer, however, had made an important mistake; for what he had estimated as oxide of cobalt consisted of oxide of cobalt and oxide of manganese, in the proportion of two parts of the former to three of the latter; the oxide of manganese being in this instance not only utterly valueless, but positively injurious.

An experienced copper-assayer, on assaying a particular ore, obtained what he believed to be nickel-speiss: that is, a compound of nickel and arsenic. Now, nickel is a valuable metal, being worth at the present time eight shillings a pound. But the supposed speiss contained not a trace of nickel, and was proved to be only a compound of iron and arsenic, a comparatively worthless product. On the ground of this assay, I believe a quantity of ore had been dressed for the market.

The following is a curious and remarkable instance of the importance of accurate chemical knowledge to the metallurgist. The Upper Hungarian Mining Company smelted, during several years, a species of copper-ore termed *fahlerz*, in ignorance of the fact that it contained mercury, which was ultimately discovered by the accidental observation of a workman. Means were then adopted to collect the mercury, of which the present annual produce amounts to 30,000*l.* in value.*

Not along ago I visited, in concert with my friend Mr. Henry, a tin-plate manufactory. In the first part of the process of tinning there is constantly formed a black powder, which from time to time is removed from the surface of the melted tin. On interrogating the manager, who conducted us over the establishment, it appeared that he was ignorant of the nature of that

* My friend Professor Szabò, of Pesth, is my authority for this statement.

powder, which Mr. Henry on subsequent examination found to contain 62 per cent. of tin in a finely divided state. He suspected that it contained silver; but his knowledge was limited to the fact that, whereas it was formerly thrown into the adjoining river, it was afterwards sold for a few pounds a ton, but now realized ten times as much.

Occasionally a large sum of money may depend upon an assayer possessing a profound knowledge of certain departments of analytical chemistry. Thus, not long ago there was a dispute between the Bank of England and the Mint respecting the re-coinage of a million of sovereigns. On melting the gold at the Mint several pounds weight of a metal were obtained which had not been previously detected by the assayer. That metal was chiefly iridium, which had been simply mechanically diffused through the gold, and which, in the state in which it was separated, was comparatively valueless. The question then arose whether the Bank or the Mint should be responsible for the loss; and it was some time before a satisfactory conclusion was arrived at. I do not mean to imply that the slightest blame was due to the assayer in this case, because he had no reason under the circumstances to suspect the presence of iridium in sensible quantity. I relate the fact, simply to show that an assayer of the precious metals may be called upon to determine the presence or absence of iridium in gold, and, I may add, of other metals also, which, for their satisfactory detection, require no ordinary skill in one of the most difficult departments of analytical chemistry.*

It would be impossible to insist too strongly upon the importance of assayers generally receiving sound instruction in the specific department of analytical chemistry, which relates to assaying.

Did time permit I could adduce many more instances in support of the proposition, that special scientific knowledge may be important to the metallurgist. I could mention one case in

* The presence of minute particles of the alloy of osmium and iridium in gold is sometimes very annoying to jewellers and watch-case makers.

which, I have been credibly informed, thousands of pounds worth of gold were lost by a blunder; and others, in which the want of scientific knowledge had occasioned heavy loss; but I have preferred placing before you those instances only upon the accuracy of which you may rely, as I have derived them either from personal knowledge or unquestionable authority. But it will not, I think, be denied, that the instances which I have adduced of themselves afford sufficient evidence of the importance, not to say necessity, of special scientific knowledge to those who are intrusted with the direction of metallurgical works. The interests at stake in such works are frequently very great, and we have seen how injuriously those interests may be affected by the want of such knowledge.

It must not be inferred from the foregoing remarks that I undervalue practical knowledge. So far from this, I am convinced that scientific apart from practical knowledge may in metallurgical establishments lead to most erroneous and occasionally ruinous results. Metallurgy is an art, and like every other art, can only be acquired by experience. In many processes success depends upon the discrimination of appearances so slight that the eye, in order to detect them, requires to be educated by close and constantly repeated observation. No description, however accurate and minute, would enable a man, though a shrewd observer, to recognise at first such appearances, and consequently to conduct processes in which success essentially depends upon their detection. To understand adequately the force of these remarks, a practical acquaintance with certain metallurgical processes is necessary.

The descriptive expressions occasionally used by the practical man may appear to be vague, and he may not be able to define them in language very intelligible to us; yet we may generally be sure that they express correctly the result of his observation, and have a meaning well understood by himself. For instance, on inspecting a blast-furnace in Staffordshire, I perceived that "tap-cinder" (slag from the puddling-furnace, rich in iron,) was introduced into the furnace with a mixture of iron ores, not then a very unusual and now a common practice. I accosted the foreman of the works, and asked him his opinion

concerning the effect which he supposed the use of "tap-cinder" would produce upon the iron. His reply was, that "cinder has no nature in it." Now the term "nature" expressed his experience of the quality of the iron when "cinder" and ore were smelted together; and, as I knew what that quality was, I knew exactly what was meant by the term in question.

The knowledge of the science of a metallurgical process would of itself be a very insufficient qualification for the man who directs the manufactory. Let a chemist, for example, who may perfectly understand the theory of copper-smelting, but who is entirely ignorant of the practice of the art, attempt to take the management of copper-smelting works, and he would find himself embarrassed at the outset: he would not be able to form a correct judgment in a single step of the process. Without experience he could not decide whether the requisite degree of heat was produced in any of the furnaces, or whether any of the various operations of smelting had been properly effected. Again: let the chemist who has received his education exclusively in the laboratory, and who, consequently, has only been accustomed to deal with small quantities, be simply required to dissolve a ton of copper in sulphuric acid, and at first he would not be a little perplexed: he would find how different the manipulation of the laboratory is from that of the manufactory; he would have to consider of what material he should construct the vessels in which to effect the solution,—of what form and size they should be,—and in what manner heat could be best applied; only the chemist who is himself practically acquainted with the manufactory will well understand the force of these remarks. I have frequently conversed with chemists who have supposed that their chemical education alone rendered them at once fully qualified to conduct operations on the large scale; and who have expressed themselves disparagingly of the practical man. Let such men attempt to conduct the manufactory, and, in all probability, it would soon be seen that the price of their obtaining the requisite practical skill would be heavy loss to the proprietors.

We are thus led to the conclusion, that while scientific knowledge alone will not qualify a man to take the management of metallurgical works, so neither is empirical knowledge

the only qualification desirable in such cases; it is clearly the combination of scientific with practical knowledge that will render the managers of such works in the highest degree competent for their responsible positions. And, accordingly, we find that our manufacturers have begun to appreciate the importance of this combination of knowledge in their managers. I could mention several establishments in which the aid of science has been sought with no inconsiderable advantage. I know that men who have received a metallurgical education on the continent are now employed in metallurgical establishments in this country; and I know many instances of English students seeking that instruction in mining and metallurgy abroad which had not been provided for them at home. It is from the combination of scientific with practical knowledge, especially in metallurgical establishments, that we may reasonably expect improvements in metallurgy. The scientific man, without practical knowledge, is likely to project schemes which, however plausible they may appear in theory, could not be profitably carried out in practice. Without experience of the working of processes on the large scale it would be impossible to form even an approximate notion of the cost of production; and the ignorance of financial considerations which the scientific man has not unfrequently displayed has, I doubt not, in many cases caused the practical man to undervalue, or even deny, the advantage of the applications of science to manufacturing art. On the other hand, the practical man has often elicited the contempt of the scientific man, by propounding unphilosophical and sometimes absurd explanations of the processes which he conducts; and it must not be forgotten that the practical man, in spite of his purely practical pretensions, will generally and, according to my experience, always be found ready with an explanation of any phenomena he may observe: indeed, the practical man, paradoxical as it may seem, abounds in theories, often in the highest degree wild and visionary. From these considerations, the importance of the combination of scientific with practical knowledge in those who direct metallurgical establishments will more clearly appear.

Although the arguments which I have already advanced may be regarded in some measure as a reply to the objection which, in

a former part of this discourse, I anticipated might be urged against the utility of providing public instruction in metallurgy in this country, yet, from its *prima facie* plausibility, it requires a more specific examination. The objection, it will be remembered, is, that as in Great Britain the practice of metallurgy has attained an unparalleled degree of development, and as this development has been effected in the absence of public instruction in metallurgy, such instruction must now be unnecessary.

By development I mean magnitude of production; but magnitude of production is no certain proof of correspondingly great skill. Let us consider first the special natural conditions under which the development in question has occurred. The largest and most important item of the metallurgical produce of Great Britain is iron; and it is precisely that item which, on comparing the amount of the metallurgical produce of Great Britain with that of other countries, makes the balance so great in favour of the former. Now, the ores of iron exist in extraordinary abundance throughout various districts of this country; and, what is very important in the consideration, the fuel necessary to the smelting of iron exists also in equal abundance, and, for the most part, in close proximity to the ores of iron. We have thus two conditions specially favourable to the production of cheap iron, abundant ore and fuel occurring together; and to these may be added the third condition of denseness of population, and, as a consequence, cheap labour. In no other country* do we find an equally favourable combination of circumstances for the production of cheap iron, not even in North America, where rich coal fields extend over a vast area, and the ores of iron exist in great profusion; for, generally, as the two do not occur together, the expense of carriage must necessarily be considerable. Moreover, as the country is as yet but comparatively thinly inhabited, the expense of labour is greater than in Great Britain. In respect, then, to the capability of the production of cheap iron our own country is at present unrivalled.

* Except, perhaps, Belgium.

But the mere smelting of iron, as compared with some other metallurgical operations, is a simple process. After the introduction of the proper admixture of ores, limestone, and fuel into the blast furnace, the only satisfactory indication of the working condition of the furnace is presented by the character of the slag as it flows out at the bottom. The quality of the metal produced from the same furnace, apparently under the same conditions, varies from time to time, even in two successive tappings.* Hence, as in the process of iron smelting there is but comparatively little opportunity for observation and interference on the part of the manager, and as under apparent identity of conditions the product may vary sensibly in quality, the operation itself cannot, in respect to the opportunity for the exercise of skill, compare with many other metallurgical processes.

But it must not be assumed that because this branch of industry has been generally carried on in this country by men who have not a scientific knowledge of the process, it would not with the aid of such knowledge have advanced to a much higher degree of perfection, whether as relates to economy of production or excellence of quality. Nor must it be assumed that because the production of iron (and in speaking of iron at the present time I mean pig-iron) appears to be a simple process, and because the men who conduct that process have frequently no scientific knowledge of it, science has done nothing towards the development of the smelting of iron in this country. Although we may not be able accurately to trace the history of improvement in many instances, yet we may be assured that the improvements which have from time to time been effected in the smelting of iron have not been altogether the result of accident or blind trial. The observation which I have just made respecting the production of pig-iron will also apply to the manufacture of bar or wrought iron, with the exception that in the latter case there is apparently much greater scope for the exercise of skill on the part of the workman and manager.

* Even in the same tapping there may be several distinct varieties of metal.

There are many problems of the highest interest in relation to the manufacture of iron and other metals at the solution of which we shall, most probably, only arrive by the aid of science. I have already alluded to the production of a slag termed "tap-cinder" in the conversion of pig or cast into bar or wrought iron. Of this slag thousands of tons have, until quite recently, been thrown away every year, notwithstanding it contains a larger quantity of iron than exists in the common argillaceous or most abundant ores of iron; and when it is introduced into the blast furnace with the ores of iron it tends in a special manner to deteriorate the quality of the iron produced. By the aid of analytical chemistry we are, I believe, enabled to determine why the use of this slag injures the quality of the iron; and thus, having a correct knowledge of the cause, we are in a better condition for devising means to counteract the defect than we should be if that cause were unknown to us.

We import annually a large quantity of foreign iron, especially for the manufacture of steel. In 1850 the importation amounted to 34,066 tons, the value of which may at least be estimated at 500,000L.* Yet, I presume, if a method should be discovered by which British iron could be satisfactorily substituted for that amount of foreign iron, such a discovery would be regarded as advantageous to this country. Many attempts have been made to effect this substitution, but hitherto with only partial, though, I may add, increasing success. Particular varieties of iron are required for the production of particular qualities of steel; and we are still, in great measure, ignorant of the precise chemical differences between these varieties of iron. But without a knowledge of these differences, the determination of which will require the highest analytical skill of the chemist, we can only make blind attempts to solve the problem in question.

* I make these numerical statements on the authority of my friend Mr. S. H. Blackwell, the author of the admirable statistical report on the iron trade in this country, contained in the Illustrated Catalogue of the Great Exhibition.

In the smelting of copper there are many points of considerable practical importance which are still very obscure, and which will certainly never be elucidated without the aid of science. Notwithstanding that copper smelting has been conducted in this country, during a long period, on a scale of unexampled magnitude, there is one point in the last part of the process,—the operation of “poleing,”—which is even not yet clearly understood: I allude to the effect of “over-poleing.” Researches have, it is true, been made on this subject, but still, as it appears to me, without a decisive result. Again, the quality of the copper produced, not only in different smelting establishments, but in the same establishment, at different times, has been found very sensibly to vary in certain respects, especially of late, in spite of the efforts of the smelter to produce a metal of uniform quality. I know, indeed, that in some instances even smelters of great experience have taken special precautions to attain this end, but still not with constant success. Now it is clear, I think, that in such cases chemistry alone will enable us to determine the causes of this variation in quality, and without a knowledge of these causes the smelter can merely grope in the dark after means to obviate the defect. Already, I know that in some instances chemistry has rendered essential service of this kind. The variations in quality to which I have alluded are frequently not in the slightest degree indicated by the appearances of the metal, and only become manifest in the different processes of manufacture to which copper is subjected; as, for example, in rolling, hammering, and stamping, in dipping, and in the peculiar and sometimes very striking defects which it occasions in alloys. At a future period I shall enter at considerable length upon these points. In illustration of the variations in the quality of copper, I may mention the fact of the very different degree of corrosion by sea-water, observed especially during the last few years in the copper sheathing of the vessels of the navy.

The smelting of lead would also appear to present a promising field for the exercise of special scientific knowledge. In this country two methods of smelting are practised, and in both the loss of lead from volatilization is very considerable, amounting to ten per

cent. or more. Accordingly, flues of great length, sometimes exceeding a mile, are constructed in order to effect as completely as possible the condensation of the lead smoke or fume. Other contrivances with the same view have been adopted; the smoke has been caused to pass through water by means of powerful exhausting pumps, or water has been projected in a finely divided state, like rain, into chambers through which the smoke has been made to circulate; and other methods have also been tried with greater or less success, but all attended with no inconsiderable outlay. Now, as my friend, Mr. John Taylor junior, remarked to me, attention should rather be directed to the improvement of the smelting process itself, by effecting, if practicable, the separation of the lead at a temperature sufficiently low to prevent volatilization. But such an improvement, admitting its practicability, is far more likely to be made by the smelter who, with a practical knowledge of the process, combines the special scientific knowledge relating to lead smelting, than by the man who possesses only the former.

In tin-smelting, also, we meet with some interesting and important problems, which would seem to require the aid of chemistry for their solution. For example, in the manufacture of the best tin-plates, the tin required is of the best quality, and has, therefore, the highest price. Tin of inferior quality, and of less value by some pounds per ton, is unfit for that purpose. Chemistry will alone explain why one kind of tin is suitable and another not; and when the causes of the difference between one quality of tin and another are known, it is not improbable that a method may be devised for converting tin of inferior into tin of superior quality, the difference of price between these qualities allowing a considerable margin, as manufacturers term it, for the expense of a process by which that conversion might be effected.

I might also, with equal propriety, allude to the manufacture of zinc, which, it is to be hoped, is not incapable of further improvement. There is at present a greater difference between the value of the ores of zinc and the zinc itself than in the case of any other metal.

Another very promising field for the exercise of science in

relation to metallurgy is presented by the various metals which have not yet received any extensive practical application. Tungsten, for example, is in this category; it exists in nature in considerable abundance, and is frequently found associated with tin ore, from which it is separated as completely as practicable, and thrown aside as worthless. It is true that attempts have recently been made to employ certain compounds of the metal in dyeing, as had previously been done thirty years ago; but these attempts have not, I believe, as yet been attended with any great success, or a demand for tungsten would have been created in consequence, which is not the case. Failures, however, should only have the effect of stimulating to further efforts in respect to the application of this metal, which, I confidently predict, will not much longer continue a comparatively worthless substance. Very substantial pecuniary emolument will, certainly, be the reward of the man who shall discover the mode of rendering tungsten extensively subservient to the arts. It is only a few years ago, that, in respect to commercial value, nickel occupied much the same position as tungsten at the present time; but now it is worth 8s. a pound, or about ten times more than copper. It is the whitening constituent of the alloy known as german silver. The silver-platers who practise the old method of plating by soldering, as well as those who deposit the silver by the agency of voltaic electricity, employ this alloy extensively, the advantage being that when the silver is worn from any part of an article, the alloy beneath sufficiently approximates to silver in whiteness as to deceive the eye respecting the wear. Some years ago, a compound of nickel, termed pottery nickel, was obtained in the manufacture of compounds of cobalt for the use of the potters, which was sold as low as three halfpence a pound, whereas it would now fetch about 3s. 6d.

Titanium is another metal, which, like tungsten, evidently exists in large quantity in nature, but which has hitherto only been applied to a very trifling extent in the arts, especially as a colouring ingredient in the manufacture of artificial teeth. I confess I am no believer in useless metals, and, therefore, with equal confidence repeat the prediction which I uttered in respect to the application of tungsten. Then, again, I may mention molybdenum, the only

practical application of which is in analytical chemistry; and cerium and vanadium, which, if required, there is reason to believe might be obtained in some quantity. We must not disregard a metal on account of its rarity; for some of the rarest metals have of late been applied with great advantage. I may mention, for instance, the native alloy of osmium and iridium, which only a very short time ago was confined to the laboratory of the scientific chemist. The alloy occurs in small grains, so intensely hard that the hardest file will not make an impression upon them. The tips of the so-called gold pens are made of these grains; but for this purpose only the larger grains can be employed. The demand for these grains in the pen-manufacture is now considerable, and the price ranges between six and eight pounds an ounce. Iridium has also been applied as a black pigment in painting on porcelain. In intensity of blackness it is said to exceed all other black porcelain colours, which by the side of the iridium-black appear more or less grey. It is only within the last few years that uranium has been employed to produce the delicate canary yellow colour in glass with which we are all familiar; but the demand for that metal is at present so considerable that there is a difficulty in supplying it. Another similar instance of successful recent application is afforded by cadmium, which occurs in small proportion in certain ores of zinc. This metal in combination with sulphur constitutes the finest and most durable opaque yellow colour with which the artist is acquainted. The metal itself has also been used in conjunction with mercury and tin for filling teeth; but certain disadvantages arising from its use have caused it to be abandoned for that purpose. I have expressly been somewhat minute in detailing the preceding instances of the successful application of metals not long since regarded as valueless to the arts, in order to excite and stimulate efforts to promote the application of the other metals which I have mentioned as still without useful application; and moreover, to encourage the hope of success by showing how extensive a field for application is presented in the various arts.

Having now, as I conceive, sufficiently established the importance of special scientific knowledge to the metallurgist, I

proceed to describe particularly the kind of instruction which I propose to impart in this institution. That instruction will be conveyed in two ways, by lectures, and by practical demonstrations in the metallurgical laboratory. The student, however, before entering upon the study of metallurgy, will be required to give satisfactory evidence of his possessing a competent knowledge of general chemistry, theoretical and practical.

In the lectures, a minute description will be given of the characters and properties of the various metals, which are properly the subject of metallurgical inquiry, and of such of their compounds as are of special metallurgical importance; for example, their combinations with oxygen, sulphur, phosphorus, silicon, carbon, &c. Their ores will next be treated of, and special attention will be devoted to the consideration of certain matters, the presence of which, even in small quantity, is liable in a marked degree to affect the quality of the metal extracted. The processes of separating the metals from their ores as prepared by the miner will be fully described; and this description will comprise ample details respecting the apparatus and mechanical appliances generally which are required in metallurgical operations, as furnaces, crucibles, blowing-engines, and rolling-mills. The various materials employed in the construction of furnaces, as fire-clay and fire-stones, will be carefully passed in review, together with the kinds of fuel used. The adventitious products which are obtained in any metallurgical processes, as the various kinds of slag or scoria, and a knowledge of which may frequently be of great practical importance, will be discussed at considerable length. The cost of production, and the more important applications of the metals, especially as alloys, and to electro-plating, will receive prominent attention, as will also the theories of the various processes described.

In the laboratory, practical instruction in assaying will be given, and in those special departments of analytical chemistry which have a particular and important bearing upon any given metallurgical process. The various methods of assaying in the case of any given metal will be compared by experiment. The student will also be specially instructed in the use of that in-

valuable instrument, the blow-pipe, which is not only constantly employed in the discrimination of minerals, but may occasionally be advantageously used in quantitative assaying. To those who may travel in distant parts of the world, the use of the blow-pipe cannot be too strongly recommended, as it frequently affords the readiest and most accurate means of determining the nature of ores; added to which, its extreme portability is a very important consideration to the traveller.

Moreover, I shall endeavour to adapt the course of study in the laboratory to the special department of metallurgy in which it is most important that the student should become proficient. Thus, in the case of a student desiring to acquire the special scientific knowledge relating to lead-smelting, I should direct his attention to that part of analytical chemistry which would enable him to ascertain the precise composition of the ores of lead and of the adventitious products obtained in lead-smelting, as lead-slugs and lead-fume; and I should also require him to demonstrate by experiment, as far as practicable in the laboratory, the reactions which take place in the process of smelting.

The lectures will be illustrated by specimens, diagrams, and models; and I may remark that in metallurgical lectures the illustrations presented to the student are of great practical value. It is essential that he should see, and examine carefully for himself, the specimens which illustrate metallurgical processes. No description, however accurate and minute, could in many cases convey to his mind precise notions of the external characters of substances with which it is important for him to be familiar. In the process of polling copper, for example, small portions of metal are taken out of the furnace at short intervals, until it presents certain specific appearances which indicate the condition of the copper, and the period when it is necessary to arrest the operation. In the smelting of iron also, certain appearances of the slag furnish characteristic indications of the working condition of the furnace. But these appearances must be seen to be understood.

The museum, I am happy to state, already possesses a metallurgical collection of considerable value, and which will, I trust, at no distant period become one of the most perfect in Europe.

The illustrations of the principal metallurgical processes of this country as the smelting of iron, copper, lead, and tin, and the manufacture of steel, are very satisfactory. The foreign collection is rapidly increasing, and will be found of great practical utility to those who direct metallurgical establishments. Indeed I know that many gentlemen connected with such establishments have visited the museum, and expressed their appreciation of the important practical bearing, especially of the foreign collection.

I may be permitted to add, that in addition to the collection arranged in the museum, I shall be able to illustrate the lectures by an extensive series of specimens which I have myself been engaged in forming during the last twelve years. This collection contains numerous examples of the defects which occur from time to time in the working of certain metals, and which frequently depend upon the presence of foreign bodies in minute proportion which have escaped detection by the smelter.

In regard to models, the metallurgical department of the museum is also in a promising condition. The metallurgist on visiting the model-room will observe that the metallurgical models have not been constructed for the purpose of amusing the casual spectator, but of instructing the student. Each will be found to possess some special feature of interest in relation to practice. The collection comprises models of various furnaces, of a blast-engine, a very beautiful and complete model of the steel works of Messrs. Naylor, Vickers, and Co., munificently presented by them to the Institution, &c.; and to these may be added apparatus used in assaying, including that of Gay-Lussac for assaying silver, (now adopted at most of the continental mints), crucibles, and other metallurgical instruments.

Having explained the nature of the instruction which I propose to impart in this Institution, I may in a few words state what I do not pretend to teach. I do not pretend to teach practical smelting, or that knowledge which can only properly be acquired by experience in the manufactory. But I do hope to be able to communicate information to the student which he will be able to apply with great advantage when, at a future period, he may be engaged in the practice of metallurgy on the great scale, by which he will be prevented from the commission

of blunders such as I have mentioned, and be placed in the best possible condition for effecting some of the many desirable improvements in metallurgical processes.

It will doubtless have been remarked, throughout this introductory discourse, that I have considered the subject of instruction in metallurgy exclusively in relation to practice, or in other words, to speak plainly, in a pounds-shillings-and-pence point of view. I have done so for special reasons. This Institution professes to be a School of Mines, the chief object of which should be to render science subservient to manufacturing art; or, what is equivalent, disguise it by words as we may, to make science remunerative. Our practical metallurgists may be men of large hearts and philanthropic views respecting the application of science to the benefit of man; but if we wish to urge upon them the importance of combining scientific with practical knowledge, we must demonstrate that that combination will be of pecuniary advantage to themselves. What care they, if deficient of a taste for science, about any novel and ingenious application, if it cannot be made productive of pecuniary emolument to themselves? What inducement can they have for investing capital to carry into practice an invention, however beautiful and attractive in a scientific point of view, apart from the consideration of gain? If we address men of business on the applications of science, we must take the business view of the matter; and, as from the very nature of my subject, I must be supposed to be speaking to men who either are or may become interested in metallurgical establishments, I have felt it incumbent upon me to speak as I have done.

But let it not be imagined that the study of metallurgy has no attractions for the man of science: so far from that being true, it is a study abounding in problems of great scientific interest, and affording ample scope for the exercise of the highest powers of research; and while the lover of abstract science will discover in it much to reward his attention, to the man who delights in the application of science to the useful purposes of life it presents peculiar charms. To the antiquarian also it will often be found to render good service; for, as the

working of metals dates from the earliest period of man's history, the remains of ancient furnaces and the products of ancient metallurgical skill not unfrequently become the subjects of archæological inquiry. It is interesting, moreover, to trace the history of the metallurgic art, and to note how the rude and laborious processes of former times have gradually acquired the marvellous development which we observe in Europe at the present day. In order to form a vivid conception of this progress, we have only to witness the Hindoos toiling laboriously at their bellows made of skin, to extract a few pounds of iron from their little furnace, scarcely larger than a chimney-pot, and then to direct our attention to the gigantic blast-furnace of modern times, urged by a blast-engine, requiring for its movement the equivalent in steam-power of a hundred horses, and yielding upwards of two hundred tons of iron a week.

As the character of this discourse is essentially practical, I should wish, before concluding, to guard myself from the imputation of undervaluing knowledge, whether literary or scientific, which appears to have no direct practical bearing. It would be furthest from my intention to utter a word in disparagement either of polite literature or abstract science. In this utilitarian age there is a danger of forgetting that the human mind is destined for a higher purpose than that of being wholly absorbed in the material realities of life. There is no incompatibility between the pursuits which elevate, refine, and delight our taste, and those which we are called upon to follow, as well for our personal advantage as for the benefit of our race. In contemplating the marvellous triumphs of human ingenuity at the present epoch of unexampled progress, we should be careful not to depreciate unjustly the character of the education which we received in youth; and we should bear in mind that, although that education may not have made us acquainted with natural objects and phenomena to the extent we might desire, it has yet been the means of subjecting the various faculties of our minds to a most salutary and invigorating discipline.

In conclusion, permit me to impress upon your attention that the chief object of the present discourse is to show the importance of special scientific knowledge to the metallurgist; and the

proof, it will be borne in mind, rests chiefly upon the instances adduced in which the want of that knowledge has been shown to have occasioned pecuniary loss. But if the proof be admitted to be satisfactory, it will then follow that the diffusion of such knowledge by public instruction must be of public advantage; for in proportion to the success with which the metallurgic art is practised in this country will the interests of the whole population directly or indirectly in no inconsiderable degree be promoted.

BOARD OF TRADE.

Department of Science and Art.

PROSPECTUS

OF THE

METROPOLITAN SCHOOL OF SCIENCE

APPLIED TO

MINING AND THE ARTS.

3d Session—1853-54.



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FOR HER MAJESTY'S STATIONERY OFFICE.

1853.



NOTICE.

The Session will commence on Saturday, the 1st day of October 1853, when the Introductory Lecture will be delivered by Professor Edward Forbes, at three o'clock, p. m.

The Chemical and Metallurgical Laboratories will be opened for Students on Monday, the 3d of October.



BOARD OF TRADE.

Department of Science and Art.

METROPOLITAN SCHOOL OF SCIENCE

APPLIED TO

MINING AND THE ARTS.

3d Session. 1853-54.

The Government School of Mines and of Science applied to the Arts, now called THE METROPOLITAN SCHOOL OF SCIENCE APPLIED TO MINING AND THE ARTS, was founded in 1851, in consequence of numerous memorials addressed to Government by the mining districts of the United Kingdom. In these memorials it was urged that the mineral produce of this country far exceeds that of any other European State, that it is equal to four ninths of the produce of the whole of Europe, and represents an annual value of 24,000,000*l*. It was shown that States far lower in the scale of production had established Schools for the instruction of persons engaged in mining pursuits, and the effect had been increased economy, efficiency, and safety in mining operations. The memorialists pointed out that the want of Mining Schools, similar to those which exist in France, Russia, Prussia, Saxony, Austria, Spain, and Sweden, has long been felt in the mining districts of this kingdom. The Government School, established in connexion with the Mu-

seum of Practical Geology, in consequence of these memorials, was opened in 1851.

At the close of that year memorials were addressed to the Commissioners of the Exhibition by the chief manufacturing towns, pointing out the importance of establishing Provincial Schools of Science in connexion with a Central Metropolitan School.

The Government regarding these memorials as a correct expression of public opinion, considered it expedient to enlarge the character of the instruction given in their School in Jermyn-street, so as to include several more important applications of Science to the Arts and useful purposes of life. The propriety of the course is confirmed by the fact, that amongst the students who entered the Government School were many persons who desired a general education in Practical Science without a special reference to Mining.

In the meantime, the public conviction as to the importance of such facilities for instruction became more distinctly manifested. The subject was brought before Parliament in the following passage of the Queen's Speech :—

“The advancement of the Fine Arts and of Practical Science will be readily recognized by you as worthy the attention of a great and enlightened nation. I have directed that a comprehensive scheme shall be laid before you, having in view the promotion of these objects, towards which I invite your aid and co-operation.”

In fulfilment of this recommendation, so far as it relates to industrial pursuits, a Department of Science and Art was instituted and attached to the Board of Trade, with the object of promoting the establishment of Local Schools and of connecting them with their Central Schools of Science and Art respectively.

The courses of instruction at the Central School of Science applied to Mining and the Arts in Jermyn-street are conducted by the following officers :—

DIRECTOR.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.

CHEMISTRY, with special reference to its applications in the Arts and Manufactures	- - - }	<i>A. W. Hofmann</i> , Ph.D., F.R.S.
NATURAL HISTORY, applied to Geology and the Arts	- - - }	<i>Edward Forbes</i> , F.R.S.
PHYSICAL SCIENCE, with its special applications	-	<i>Robert Hunt</i> ,
APPLIED MECHANICS,	- - -	<i>Robert Willis</i> , M.A., F.R.S.
METALLURGY, with its special applications	-	<i>John Percy</i> , M.D., F.R.S.
GEOLOGY, with its practical applications	- -	<i>A. C. Ramsay</i> , F.R.S.
MINING,	{	<i>Warington W. Smyth</i> , M.A., F.G.S.
MINERALOGY,		

REGISTRAR.—TRENHAM REEKS.

The chief object and distinctive character of this Institution (to which everything else is made subsidiary) is to give a practical direction to the course of scientific study. Although the education provided in it, will not of itself qualify the student to undertake the direction of mining and other technical operations, yet the knowledge which he may acquire of the principles of the Sciences on which the Arts are respectively based, will in combination with future training render him in the highest degree competent, not only to engage in any special branch of industry, but to promote its further development.

The mode of instruction is by Lectures, by written and oral Examinations, by practical teaching in the Laboratories and Drawing Office, and also by Field Surveying and Excursions.

The Museum.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum, extensive collections have been and continue to be formed, illustrative of the structure of the British islands and of the applications of Geology to the useful purposes of life. These collections include several series of igneous and stratified rocks, the former arranged lithologically, and with reference to the nature of the products of modern and ancient volcanoes, the latter partly in order of superposition and partly with reference to their mode of accumulation, and the subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of

the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used in the construction of public works and buildings, and of those employed for ornamental purposes, or for chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are illustrated, and examples of the results are displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiarities of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of mining in different districts. To these will be added, from time to time, models and specimens of machinery and tools for general purposes.

The Museum is open gratuitously to the Public for the first three days of the week.

Geological Surveys.

The Geological Surveys of the United Kingdom are under the general direction of Sir Henry T. De la Beche, and their central office is at the Museum. In this office the maps and sections are prepared and deposited. Field Instruction in the various departments of Geological Surveying is given under certain conditions by the Mining, the Geological, and the Palæontological Professors.

The Mining Record Office.

This office, superintended by Mr. Robert Hunt, was established for the preservation of Mining Records: such as plans and sections of existing mines and of those which have been abandoned; also for collecting statistical information connected with the mining interests of the country.

Attempts attended with considerable loss of capital have frequently been made to mine in localities, in which a little knowledge would have shown there was small prospect of success. Through ignorance of old and deserted mine workings, great danger to the miner is not uncommonly incurred, and human life has been frequently sacrificed. The preservation of Mining Records has for its object the prevention of the loss of life or of property.

A large collection of plans and sections of mines, and important statistical details, are deposited in this Office. These are made available for the instruction of students, and may, at all times, under certain necessary regulations, be consulted by those who are interested in the mineral productions of the United Kingdom.

Laboratories.

Chemical Laboratory.

The general Laboratory for instruction in chemical manipulation, in qualitative and quantitative analysis, and in the method of performing chemical researches, is under the direction of Dr. Hofmann. The ROYAL COLLEGE OF CHEMISTRY has recently become the property of the Government, and its spacious and well-furnished Laboratories are now used for the instruction of the pupils of the Metropolitan School of Science applied to Mining and the Arts.

The Laboratory instruction, which is divided into a *qualitative* and *quantitative* course, is necessarily adapted to the previous knowledge of the student, such as he may have acquired by attending the chemical lectures delivered at the Institution. The course commences with experimental exercises, calculated to make the pupil *practically* acquainted with the *general* properties of the simple substances. The next subjects of his study are the *analytical* properties of the elements, and of their most important compounds. The knowledge thus acquired is subsequently put into practice in the performance of a series of analyses, so arranged as to lead the student, step by step, from

the simplest to the most complicated cases, both of qualitative and quantitative analysis. Particular attention is paid to the use of the blow-pipe, and the various methods of commercial testing, alkalimetry, chlorimetry, &c.

The fundamental studies in Practical Chemistry are the same for all pupils, however different the future pursuit may be to which the knowledge obtained will be applied. It is only after having mastered the most important methods of distinguishing, separating, and estimating substances, and after having acquired sufficient practice and skill in experiment, that the course of each student diverges into some special line. This will of course vary with his abilities and his ultimate objects.

Each laboratory student works independently; there are no classes. All operations are superintended by the Professor and his assistants. A table with drawers, cupboard, and shelves, is appropriated to every pupil. The Institution supplies gas, fuel, and re-agents. Larger and more expensive instruments, such as air-pumps, thermometers, barometers, condensers, large evaporating dishes, &c. may be had on loan from the Laboratory. The student has to provide himself only with the apparatus specified in the Laboratory Regulations.

Metallurgical Laboratory.

This Laboratory is under the direction of Dr. Percy, and is devoted to practical instruction in Metallurgy. The nature of this instruction will be adapted to the special requirements of the student. It comprises,—

1. Assaying in all its branches, especially of the more important metals, such as iron, copper, lead, tin, alloys of silver and gold, &c.
 2. Blow-pipe practice, with particular reference to *quantitative* as well as *qualitative* examinations.
 3. Quantitative analyses of ores and metallurgical products. This is a very important department of practical metallurgy, and is essential to those who desire to be able to investigate the principles of any metallurgical process.
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Natural History Department.

As the relative age and sequence of Geological formations are, to a great extent, determined by the evidence of Fossils, it has been found necessary in the prosecution of the Geological Survey, to establish a department of Natural History, the direction of which is confided to Professor E. Forbes, under whose charge the organic remains contained in the sedimentary rocks of the British islands and colonies are examined, prepared, and classified in stratigraphical order. These collections, as well as others consisting of select illustrative specimens from various countries, are used for the instruction of students; the former and principal are exposed for public inspection.

LECTURES.

Courses of lectures on the following subjects will be given during the Session :—

Chemistry.

The course of Lectures upon Chemistry is both theoretical and practical. The general laws of chemical affinity and combination will be fully explained, both with reference to the abstract discoveries of the Science, and to their practical applications. The first part of the lectures embraces Inorganic Chemistry, and will treat of the chemical history of the more important mineral compounds and their uses in the arts and manufactures. Among the technical subjects specially considered, and which will be introduced systematically in the course, may be mentioned,—the conditions of water-supply for domestic purposes; purification of water; artificial mineral waters; phosphorus, and the manufacture of lucifer and other matches; the manufacture of sulphuric acid; potash and its salts; nitrate of potash, nitric acid, gunpowder, chlorate of potash; soda salts; technology of common salt, hydrochloric acid, sulphate of soda, &c.; borax and boracic acid; lime-salts; bleaching powder; mortars and cements; glass and pottery; manufacture of alum; salts of the metals, sulphates of iron, copper, &c.; fuel; gas, and products of distillation of coal, &c.

Organic Chemistry, which forms the second part of the course, will be treated in the same manner. Among the technical subjects introduced under this head may be mentioned,—wood, peat; starch, sugar, and gums; fermented liquors; organic colouring matters; bleaching, dyeing, and printing of textile materials; leather; oils, vegetable and animal, and their products, as candles, soap, &c.; ammoniacal salts; prussiates of potash and Prussian blue; gelatine, glue, &c.; animal black, &c.

Metallurgy.

The course of instruction in Metallurgy consists of lectures and laboratory practice. The lectures embrace the following subjects:—

- I. General considerations on the nature of metallurgical processes.
- II. On fuel. Estimation and comparison of the calorific power of various kinds of fuel.
- III. On the materials used in the construction of furnaces and metallurgical apparatus. Fire-clay, &c. Manufacture of fire-bricks, crucibles, &c.
- IV. Special metallurgical processes.
 - a.* Copper-smelting; causes of the varieties of copper.
 - b.* Extraction of zinc from its ores. Brass and preparation of calamine brass. Various alloys of copper and zinc used in the arts; dipping, lacquering, and bronzing.
 - c.* Lead-smelting. Refining and de-silverizing. Treatment of argentiferous copper.
 - d.* Smelting of silver ores. Amalgamation by the American and Freiberg processes; other methods of extracting silver from its ores.
 - e.* Treatment of gold ores. Methods of parting gold and silver on the large scale. Alloys of gold and silver for monetary and other purposes. Modes of assaying, with special reference to standards of common occurrence.
 - f.* Extraction of mercury by various methods.

- g.* Extraction of antimony from its ores. Alloys of antimony; type metal, &c.
- h.* Extraction of bismuth from its ores.
- i.* Extraction of nickel from its ores. Production of German silver.
- k.* Treatment of cobalt ores. Manufacture of zaffre, and cobalt colours. Analysis of ores containing nickel and cobalt.
- l.* Preparation of metallic arsenic and its compounds used in the arts, as arsenious acid, &c.
- m.* Preparation and smelting of tin ores.
- n.* Smelting and manufacture of iron. Steel.
- o.* Preparation of the metals of rarer application in the arts, as cadmium, uranium, platinum, palladium, iridium.

V. The principles and practice of electro-metallurgy.

The object of the lectures is the communication of such instruction as the student may be able to apply to the greatest practical advantage, when he may be subsequently engaged in conducting any metallurgical process.

Geology.

This course will include, first, a detailed account of the geological processes now in action on the surface and in the interior of the earth, as far as they are understood. This will embrace the proofs of the origin of stratified rocks, resulting from degradation of the land, produced by the action of rain, rivers, frost, glaciers, icebergs, &c. The nature of marine denudation (the destruction of land by the sea) will be explained. In connexion with these subjects, the transport of matter by rivers, mechanically and in solution, the formation of deltas, &c., will be examined, and the general accumulation of great deposits of marine and freshwater strata. The theory of salt lakes will also be explained. Also, the proofs that large areas of the earth's surface are now being slowly elevated above, or depressed beneath the sea. The connexion of coral reefs and of earthquake and volcanic phenomena with this subject will be

fully discussed, and the analogies traced between existing volcanic phenomena and those of past geological periods. The relation of these subjects to the mode of occurrence of organic remains in the rocks, and of the consolidation of strata generally, will form a branch of this part of the subject. An account of the more important substances entering into the composition of rocks will also be given, together with an explanation of geological terms, &c.

The second part of the course will include a descriptive account of the whole series of geological formations, showing their stratigraphical order, manner of deposition, the general nature of their organic remains, and the igneous rocks with which they are occasionally associated. The origin and distribution of coal, iron, and other metals, of rock-salt, &c. &c., come under this part of the course. The laws by which questions connected with these and other important subjects are determinable will be explained, together with the connexion of Geology with questions bearing on physical geography.

An account will also be given of the use of instruments and the mode of conducting geological surveys, and of the economic bearings of the subject generally.

Natural History applied to Geology.

The subject will be treated in two courses, viz. :—

I. *The Principles of Natural History.*

This division embraces the consideration of the distinctive features of organized beings,—the several categories under which all organized beings fall; viz.—1. *Series*; 2. *Type*; 3. *Genus*; 4. *Species*; 5. *Individual*; with their phenomena of change, their mutual relations, and their relations to time and space.

A general outline of the animal and vegetable kingdoms, with a detailed inquiry into the orders and tribes, a knowledge of which is of most consequence to the geologist. The groups will be studied in ascending order, *i.e.*, in order of progression of organization.

A detailed view of the distribution of organized beings, and the laws that determine it at the present time, with a preliminary outline of the distribution of extinct creatures.

II. *Special Palæontology.*

This division is intended for advanced students, and for persons who have already made some progress in Geology.

The order of its subdivisions will be as follows:—

- a. The phenomena of life during the later tertiary epochs, especially the periods of deposition of the several stages of the crag, and those of the glacial epoch and subsequent state of things, preceding the present or historical epoch.
- b. The palæontology of the older tertiary epochs, from the so-called “lower miocene,” to the lowest eocenes.
- c. The palæontology of the upper and lower divisions of the mesozoic epochs.
- d. The palæontology of the upper and lower divisions of the palæozoic epochs.

Practical exercises in the determination and description of fossils, and excursions to geological localities in the neighbourhood of London, will form part of this section of the course.

Mineralogy.

The lectures, which will be illustrated by specimens intended for close inspection, comprise:—

I. Crystallography, an introduction to this science, showing the leading classification of the crystalline forms, the laws by which their variations are determined, and their combinations, all considered with reference to the forms actually met with among crystallised substances.

II. The physical properties of minerals, treated principally with a view to the practical discrimination of the various species.

III. The elements of the chemistry of Mineralogy, with the use of the blow-pipe, and of such tests as are calculated to be serviceable to the miner, the geologist, the scientific traveller, or the general observer when in the field.

IV. The physiography or systematic description of minerals, including all the more important species and varieties, with particular reference to the mode and places of occurrence, both for those substances which bear a commercial value, and for those which derive their chief interest from geological and physical considerations.

Mining.

I. Detailed discussion of known facts connected with the deposits of the useful minerals; beds, strata, or seams; stream-works; lodes or mineral veins; flats; pipe-veins; stock-works; irregular masses; dislocations, and rules for searching for the dislocated and lost portion of a deposit.

II. Preliminary researches, trenching, and costeaning.

III. Boring, as practised with different apparatus, with rods or rope, and with a great variety of cutting implements.

IV. Tools employed in mining, in hard and in soft ground; in collieries and in metallic mines; blasting by various methods.

V. Principles of employment of mining labour.

VI. Modes of gaining access to, and lighting subterranean cavities, including a comparison of the various safety lamps.

VII. Levels and shafts, or the main openings to underground works; driving and sinking.

VIII. Means of securing excavations by timbering, masonry, and tubbing.

IX. Exploitation, or the working away of veins and of strata.

X. Carriage or transport of minerals through the underground roads.

XI. Winding or raising in the shafts, with the machinery and apparatus required.

XII. Pumps and pumping engines.

XIII. Ventilation, its principles and practice; natural ventilation; artificial introduction of a moving power; distribution of air through the workings.

XIV. The mechanical preparation or dressing of ores.

Physical Science.

This subject will be treated of in two courses; the first being elementary; while the second will be devoted to the special applications.

I. *Elementary Course.*

I. Consideration of the general properties of matter; atomic constitution; molecular forces; cohesion; gravitation; the laws of motion.

II. Hydrostatics; equilibrium of liquids; pressure of fluids; specific gravity.

III. Hydraulics; motion of liquids and gases; atmospheric phenomena; Mariotte's law; pressure; diffusion, &c.

IV. Heat; general phenomena of solar and terrestrial heat; laws of communication,—radiation and conduction of heat; dilatation of solids, liquids, and gases; specific heat; formation of vapour; ebullition of liquids; atmospheric phenomena dependent on heat; thermometry; hygrometry; general meteorology.

V. Light; reflection, refraction, decomposition of light; colour; achromatism; vision; undulatory theory; polarization of light; chemical action of the solar and other rays.

VI. Electricity; general phenomena; machine electricity; atmospheric and animal electricity. Chemical or Voltaic electricity; electro-chemical decomposition. Magnetism; terrestrial magnetism; electro-magnetism; magneto-electricity; dia-magnetism.

II. *Practical Course.*

I. Moving bodies; weight; balances; pendulums; simple and compound; applications of the pendulum.

II. Hydrostatic press; hydraulic machines; water-supply of towns; gasometers; gas-supply.

III. Barometers; pneumatic machines and engines; diving bell; aerostation.

IV. Applications of heat; production of steam; apparatus for heating; ventilation.

V. Photometry; optical instruments; telescope; microscope; stereoscope; polariscopes; optical saccharometer.

VI. Lightning conductors; electrical machines; voltaic batteries; electro-magnets; electro-magnetic engines; electric telegraphs, &c.

Applied Mechanics.

Principles of mechanism and mechanics, with their practical applications; friction; elasticity; strength of materials, &c.; regulators of velocity and dynamometers; steam engines, and other moving powers; general construction, arrangement, and framing of machines, and forms of their individual parts.

Machines considered with respect to their purposes; as, for direct use; or for the manufacture of spun, woven, and other similar fabrics; of metals, including mining machinery; of various vegetable and animal substances, &c. &c.

Fixed structures, as arches, roofs, &c.

Mechanical Drawing.

Instruction will be given in mechanical drawing, to enable the student to make correct drawings from apparatus and machinery, and to prepare the working drawings requisite for the guidance of the founder, smith, carpenter, and others in the construction of engines, engine-houses, machinery, and apparatus in general.

Plan of Instruction.

It has been found that a student cannot advantageously devote equal attention to all the sciences taught in the School, and experience has shown that several classes of students attend its courses; viz., those who desire to pursue scientific study without reference to a preparation for any special branch of industry; those who propose to become Miners or Metallurgists; and those who are to engage in Manufactures, whether chiefly depending on chemical or on

mechanical principles. For each of these classes a special scheme of instruction is proposed in the following plans, which are recommended for adoption, although they are not compulsory, since variations may be necessary in particular cases. Besides the division for these classes, a section for working men is added; the instruction in this department being given in the evening.

The divisions of study are as follows:—

- A. GENERAL DIVISION**, for those who desire a general knowledge of applied science.
- B. MINING AND METALLURGICAL DIVISION**, for students who intend to pursue Mining or Metallurgy.
- C. TECHNICAL DIVISION**, for those who propose to engage in other arts or manufactures depending either chiefly on Chemical, or chiefly on Mechanical Principles.
- D. WORKING MEN'S DIVISION**, for the instruction of Working Men by Evening Lectures.

The students entering the Divisions B. and C. are required to follow the course of study prescribed in the following scheme:—

1st YEAR.

FOR ALL DIVISIONS.

1st TERM.	2d TERM.	3d TERM.
<i>October to January.</i>	<i>January to April.</i>	<i>April to August.</i>
Inorganic Chemistry.	Inorganic Chemistry.	Organic Chemistry.
Physics (1st Course).	Laboratory Practice.	Laboratory Practice.
Mineralogy.	Geology.	Natural History.
		Physics (2d Course)

2d YEAR.

A. GENERAL DIVISION.

1st TERM.	2d TERM.	3d TERM.
Laboratory Practice.	Laboratory Practice.	Applied Mechanics.
	Palæontology.	
	Applied Mechanics.	

2d YEAR.

B. MINING AND METALLURGICAL DIVISION.

1st TERM.	2d TERM.	3d TERM.
Metallurgy, with Practice in Laboratory. Mechanical Drawing.	Metallurgy, with Practice in Laboratory for the Metallurgical Student. Applied Mechanics. Palæontology for the Mining Student only. Mining.	Applied Mechanics. Practice in Laboratory, for the Metallurgical Student. Geological, Mineral, and Palæontological Excursions for the Mining Student.

2d YEAR.

C. TECHNICAL DIVISION.

1st TERM.	2d TERM.	3d TERM.
Chemical Laboratory Practice. Mechanical Drawing.	Chemical Laboratory Practice. Applied Mechanics. Mechanical Drawing.	Chemical or Metallurgical Laboratory Practice. Applied Mechanics.

D. WORKING MEN'S DIVISION.

Short courses of Lectures at suitable periods of the year are given in the evening to Working Men. These courses are systematic, and are arranged so as to illustrate, within the period of two years, the principal subjects taught at the Institution. Those for the ensuing Session include—

Chemistry.
Metallurgy.
Mining and Mineralogy.
Applied Mechanics.

Exhibitions.

There are various Exhibitions attached to the School, some of them being general,—open to all pupils; the others being special, and connected with particular Provincial Schools.

I.—H.R.H. The Duke of Cornwall's Exhibition.

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted two Exhibitions of thirty pounds each. One becomes

vacant every year, and will be competed for by Matriculated Students only, at the end of the first Session. It is held by the successful competitor for two years.

II.—*Council Exhibitions.*

The Educational Council of the School in order to encourage meritorious pupils, grant two Exhibitions tenable for one year by those pupils who pass the best examinations after the end of the second year. These Council Exhibitions entitle the students holding them to attend the Second Course of Lectures without payment.

III.—*Provincial Exhibitions.*

The Department of Science and Art provides Scholarships to certain of the Provincial Schools in connexion with the Metropolitan School of Science applied to Mining and the Arts. The direct sums attached to these vary in amount, but further sums may be obtained by pupils holding them, according to their standing at the Examination of the School.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of passing through the two years course of study and eventually obtaining the Diploma of the Institution, must be at least 16 years of age, and will be required to furnish certificates or other evidence of their having received a sufficient preliminary education. The study of the elements of algebra and geometry, as well as the practice of drawing, are particularly recommended to those who propose to enter the School.

THE FEE for MATRICULATED STUDENTS is *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures. The Matriculated Students have the privilege of competing for the Duke of Cornwall's and the Council Exhibitions, and of obtaining the Diploma of the Institution; they have also constant access to the Library and Museum.

The charge for instruction in the Chemical and Metallurgical Laboratories (which is not included in the above) is *ten pounds* for the Term of fourteen weeks. The Laboratories are open to Occasional as well as Matriculated Students.

OCCASIONAL STUDENTS will be admitted to the Lectures on payment of *four pounds* for each Course of above forty Lectures, and *three pounds* for the Course of forty and under.

PERPETUAL TICKETS are issued, which entitle the holder to attend all the Courses of Lectures, upon payment of *forty pounds*.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, in the Queen's or the Honourable East India Company's Service, are admitted on similar terms.

The Session will commence on Saturday, the 1st day of October 1853, when the Introductory Lecture will be delivered by Professor Edward Forbes, at three o'clock. The Chemical and Metallurgical Laboratories will open for Students on Monday, the 3d day of October.

Particulars respecting the times of Lectures, and all other information, may be obtained by application to Mr. TRENHAM REEKS, Registrar, at the School, Museum of Practical Geology, Jermyn-street, London.



LIST OF GEOLOGICAL MAPS AND SECTIONS OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM,

PUBLISHED BY MESSRS. LONGMAN & CO. FOR HER MAJESTY'S STATIONERY OFFICE.

THE Maps are those of the Ordnance Survey, Geologically Coloured by the Geological Survey of Great Britain and Ireland, under the Superintendence of Sir HENRY DE LA BECHE, C.B., Director-General. The various Formations are traced and coloured in all their Subdivisions.

GREAT BRITAIN:—The Counties of which the Geological Survey is completed, are —

- BRECKNOCKSHIRE, Sheets 36, 41, 42, 56 (NW & SW), 57 (NE & SE). Sheets, 2*l.* 0*s.* 6*d.*
 CARDIGANSHIRE, 40, 41, 56 (NW & SW), 57, 58, 59 (SE), 60 (SW). Sheets, 1*l.* 17*s.*
 CARMARTHENSHIRE, 37, 38, 40, 41, 42 (NW & SW), 56 (SW), 57 (SW & SE). 1*l.* 19*s.*
 CAERNARVON, 74 (NW), 75, 76, 77 (N), 78, 79 (NW & SW). Sheets, 1*l.* 18*s.*
 CORNWALL, including Sheets 24, 25, 26, 29, 30, 31, 32, & 33. Sheets, 2*l.* 5*s.*
 DEVONSHIRE, including Sheets 20, 21, 22, 23, 24, 25, 26, 27, & 29. Sheets, 2*l.* 11*s.*
 * * The Geology of the Counties of CORNWALL and DEVON is amply illustrated by Sir H. De la Beche's "Report." Svo. 14*s.*
- GLAMORGANSHIRE, including Sheets 20, 36, 37, 41, & 42 (SE & SW). Sheets, 2*l.*
 * * Horizontal Sections, 14*s.*; Vertical, 25*s.*; illustrate this County.
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17. [South West of Dorset.] 7*s.*
 18. [Northern half of Dorset, and South-eastern part of Somerset.] 12*s.*
 19. [Half of Somerset, and part of West Wilts.] 11*s.* 6*d.*
 20. [West Somerset and part of South Glamorgan.] 5*s.* 6*d.*
 21. [SW. Somerset, NE. Devon, and part of West Dorset.] 10*s.*
 22. [Part of SE. Devon.] 7*s.*
 23. [Devon between Torbay and Start Point.] 3*s.*
 24. [Part of South Devon and of Cornwall.] 3*s.* 6*d.*
 25. [SW. Devon and East Cornwall.] 10*s.*
 26. [West Devon and NE. Cornwall.] 6*s.*
 27. [Devonian Rocks.] 3*s.* 6*d.*
 28. [Lundy Island.] 2*s.* 6*d.*
 29. [The North of Cornwall, showing the Coast line from Hartland Quay to Cambeak.] 2*s.* 6*d.*
 30. [Part of Cornwall.] 7*s.* 6*d.*
 31. [Part of Cornwall.] 7*s.* 6*d.*
 32. [Part of Cornwall.] 3*s.*
 33. [Part of Cornwall.] 5*s.*
 35. [Western Gloucester, the SE. of Monmouth, part of North Somerset and West Wilts.] 10*s.*
 36. [The greater part of Glamorgan on the West, and Monmouth on the East.] 13*s.*
 37. [West Glamorgan and South Carmarthen.] 8*s.*
 38. [South Pembroke.] 4*s.*
 39. [Small's Light, Pembroke.] 2*s.* 6*d.*
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 41. [Most of Carmarthen, parts of North Glamorgan, South Cardigan, and East Pembroke.] 8*s.*
 42 NW. [West Brecknock and part of East Carmarthen.] 2*s.*
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 43 SW. [The West of Dean Forest Coalfield.] 3*s.*
 44 SE. [The greater part of Dean Forest Coalfield.] 3*s.*
 44 NW. [Part of Worcestershire.] 2*s.*
 45 NE. [Part of Shropshire and Worcestershire.] 3*s.* 4*d.*
 45 NW. [Part of Hereford, Worcester, and Shropshire.] 3*s.*
 45 SW. [Part of Hereford.] 2*s.* 6*d.*
 45 SE. [Part of Hereford and Worcester.] 2*s.* 6*d.*
 46 NW. [Part of Brecon, Cardigan, Radnor, and Montgomery.] 2*s.* 6*d.*
 46 NE. [Part of Radnor, Montgomery and Shropshire.] 2*s.* 6*d.*
 46 SW. [Part of Radnor, Brecon, and Carmarthen.] 3*s.*
 46 SE. [Part of Radnor and Hereford.] 2*s.* 6*d.*
 47 NW. [Part of Cardiganshire.] 1*s.*
 47 NE. [Part of Cardiganshire.] 2*s.* 6*d.*
 47 SW. [Part of Cardiganshire.] 1*s.* 6*d.*
- 57 SE. [Part of Cardiganshire, including Lampeter to Tro-garron.] 2*s.*
 58. [Part of the Coast of Cardiganshire (Cardigan) and N. Pembrokeshire.] 2*s.* 6*d.*
 59 NW. [Sea.]
 59 NE. [Part of Cardigan, Montgomery, and Merioneth.] 3*s.*
 59 SW. [Sea. (No Geological Colouring.)] 6*d.*
 59 SE. [The North of Cardiganshire; part of the West of Montgomery and the South of Merionethshire.] 3*s.*
 60 NW. [Part of Montgomery and Merioneth.] 2*s.* 6*d.*
 60 NE. [Part of Montgomery and Shropshire.] 2*s.* 6*d.*
 60 SW. [Part of Cardigan, Montgomery, and Shropshire.] 3*s.*
 60 SE. [Part of Montgomery, Radnor, and Shropshire.] 3*s.*
 61 NW. [Part of Shropshire.] 2*s.* 6*d.*
 61 NE. [Part of Shropshire and Staffordshire.] 3*s.*
 61 SW. [Part of Shropshire.] 3*s.*
 61 SE. [Part of Shropshire.] 3*s.* 6*d.*
 62 SW. [Part of Staffordshire, including the Coalfield.] 3*s.*
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 72 SE. [Part of Staffordshire and SW. Derbyshire.] 2*s.*
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 74 NE. [Part of Denbigh, Flint, Shropshire, and Merioneth.] 3*s.*
 74 SW. [Part of Montgomery, Denbigh, and Merioneth.] 3*s.*
 74 SE. [Part of Shropshire, Montgomery, and Denbigh.] 3*s.*
 75 NW. [Part of Caernarvon.] 2*s.*
 75 NE. [Part of Caernarvon, Merioneth, and Denbigh.] 3*s.* 6*d.*
 75 SW. [Part of Caernarvon.] 2*s.*
 75 SE. [Part of Merioneth.] 3*s.* 6*d.*
 76 N. [Part of Caernarvon.] 1*s.*
 76 S. [Part of Caernarvon.] 1*s.* 6*d.*
 77 N. [Part of Holyhead Island.] 1*s.* 6*d.*
 78 NW. [N. part of Anglesea and part of Holyhead Island.] 4*s.*
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 78 SE. [Part of Anglesea on Menai Straits, NE. of Caernarvonshire, and W. of Denbighshire.] 5*s.* 6*d.*
 79 NW. [Part of Flint, Denbigh, and Caernarvon.] 2*s.* 6*d.*
 79 NE. [Part of Flint, Cheshire, and Lancashire.] 2*s.*
 79 SW. [Part of Flint, Caernarvon, and Denbighshire.] 2*s.* 6*d.*
 79 SE. [Part of Cheshire, Flint, and Denbigh.] 3*s.* 6*d.*
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HORIZONTAL SECTIONS,

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Illustrative of the Horizontal Sections and Maps of the Geological Survey.

These Sections are arranged, in the form of Vertical Columns, to a scale of 40 ft. to an inch, and illustrate such details as it is impossible to give in the Horizontal Sections above described. In the Coal Measure Sections, for instance, the Thickness of each Bed of Coal, the Mineral Structure and Thickness of the Strata with which they are associated, and the kind and Amount of Ironstone, are given in the greatest detail. Sheets 1 to 18, price 5s. each Sheet.

MAPS OF IRELAND.

INDEX MAP of CARLOW, Geologically coloured, price 7s.			
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INDEX MAP of WEXFORD, Geologically coloured, price 7s.
Horizontal Sections to WICKLOW, 4 Sheets. 7s. each.
Plan and Sections of the OVOCA MINES. 7s.

BOOKS Published under the Superintendence of the Geological Survey.

REPORT on CORNWALL, DEVON, and WEST SOMERSET. By Sir H. T. DE LA BECHE, F.R.S. &c. 8vo. 14s.
 FIGURES and DESCRIPTIONS of the PALÆOZOIC FOSSILS in the above Counties. By PROFESSOR PHILLIPS. 8vo. 14s.
 THE MEMOIRS of the GEOLOGICAL SURVEY of GREAT BRITAIN, and of the MUSEUM of ECONOMIC GEOLOGY of LONDON. 8vo. Vol. I. 21s.; Vol. II. (in 2 Parts), 42s.
 BRITISH ORGANIC REMAINS. Forming a portion of the Memoirs of the Geological Survey. Decades I. II. III. IV. V. and VI. with 10 Plates each. Royal 4to. 4s. 6d.; or royal 8vo. 2s. 6d. each Decade.—Other DECADES are in the Press.
 RECORDS of the SCHOOL OF MINES and of SCIENCE applied to the ARTS. Vol. I. Part I. Inaugural and Introductory Lectures to the Courses for the Session 1851-52. Royal 8vo. price 1s. 6d. cloth. Vol. I. Part II. On the Geology of the South Staffordshire Coalfield. By J. BEETE JUKES, M.A., F.R.S., &c. Price 2s. 6d.

These Maps, Sections, and Books may be obtained at the Geological Survey Office, Museum of Practical Geology, Jermyn-street, London.

BOARD OF TRADE.

Department of Science and Art.

PROSPECTUS

OF THE

METROPOLITAN SCHOOL OF SCIENCE

APPLIED TO

MINING AND THE ARTS.

4th Session. 1854-55.



LONDON:

PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,

PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.

FOR HER MAJESTY'S STATIONERY OFFICE.

1854.



NOTICE.

The Chemical Lectures will commence and the Laboratories will be opened for the Students on Monday, the 2nd of October 1854. The Metallurgical Course will commence on the 16th of October, the Lectures on Natural History, Mineralogy, and Physics early in November, and the remainder of the Courses in January 1855.



BOARD OF TRADE.

Department of Science and Art.

METROPOLITAN SCHOOL OF SCIENCE

APPLIED TO

MINING AND THE ARTS.

4th Session. 1854-55.

The Government School of Mines and of Science applied to the Arts, now called THE METROPOLITAN SCHOOL OF SCIENCE APPLIED TO MINING AND THE ARTS, was founded in 1851, in consequence of numerous memorials addressed to Government by the mining districts of the United Kingdom. In these memorials it was urged that the mineral produce of this country far exceeds that of any other European State, that it is equal to four ninths of the produce of the whole of Europe, and represents an annual value of 24,000,000*l*. It was shown that States far lower in the scale of production had established Schools for the instruction of persons engaged in mining pursuits, and the effect had been increased economy, efficiency, and safety in mining operations. The memorialists pointed out that the want of Mining Schools, similar to those which exist in France, Russia, Prussia, Saxony, Austria, Spain, and Sweden, has long been felt in the mining districts of this kingdom. The Government School, established in connexion with the Mu-

seum of Practical Geology, in consequence of these memorials, was opened in 1851.

At the close of that year memorials were addressed to the Commissioners of the Exhibition by the chief manufacturing towns, pointing out the importance of establishing Provincial Schools of Science in connexion with a Central Metropolitan School.

The Government regarding these memorials as a correct expression of public opinion, considered it expedient to enlarge the character of the instruction given in their School in Jermyn-street, so as to include several more important applications of Science to the Arts and useful purposes of life. The propriety of this course is confirmed by the fact, that amongst the students who entered the Government School were many persons who desired a general education in Practical Science without a special reference to Mining.

In the meantime, the public conviction as to the importance of such facilities for instruction became more distinctly manifested. The subject was brought before Parliament in the following passage of the Queen's Speech :—

“The advancement of the Fine Arts and of Practical Science will be readily recognized by you as worthy the attention of a great and enlightened nation. I have directed that a comprehensive scheme shall be laid before you, having in view the promotion of these objects, towards which I invite your aid and co-operation.”

In fulfilment of this recommendation, so far as it relates to industrial pursuits, a Department of Science and Art was instituted and attached to the Board of Trade, with the object of promoting the establishment of Local Schools and of extending to them the advantages of the Central Schools of Science and Art respectively.

The courses of instruction at the Central School of Science applied to Mining and the Arts in Jermyn-street are conducted by the following officers :—

DIRECTOR.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.

CHEMISTRY, with special reference to its applica-	}	A. W. Hofmann, Ph.D., F.R.S.
tions in the Arts and Manufactures		
GENERAL NATURAL HISTORY	-	- T. H. Huxley, F.R.S.
PHYSICS	-	- George G. Stokes, M.A., F.R.S.
APPLIED MECHANICS	-	- Robert Willis, M.A., F.R.S.
METALLURGY	-	- John Percy, M.D., F.R.S.
GEOLOGY	-	- A. C. Ramsay, F.R.S.
MINING,	}	- Warrington W. Smyth, M.A.,
MINERALOGY,		

REGISTRAR.—TRENHAM REEKS.

The chief object and distinctive character of this Institution (to which everything else is made subsidiary) is to give a practical direction to the course of scientific study. Although the education provided in it, will not of itself qualify the student to undertake the direction of mining and other technical operations, yet the knowledge which he may acquire of the principles of the Sciences on which the Arts are respectively based, will, in combination with future training, render him in the highest degree competent, not only to engage in any special branch of industry, but to promote its further development.

The mode of instruction is by Lectures, by written and oral Examinations, by practical teaching in the Laboratories and Drawing Office, and also by Field Surveying and Excursions, under certain conditions.

The Museum.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum, extensive collections have been and continue to be formed, illustrative of the structure of the British islands and of the applications of Geology to the useful purposes of life. These collections include several series of igneous and stratified rocks, the former arranged lithologically and with reference to the nature of the products of modern and ancient volcanoes, the latter partly in order of superposition and partly with reference to their mode of accumulation, and the

subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used in the construction of public works and buildings, and of those employed for ornamental purposes, or for chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are illustrated, and examples of the results are displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiarities of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of mining in different districts. To these will be added, from time to time, models and specimens of machinery and tools for general purposes.

The Museum is open gratuitously to the Public for the first three days of the week.

Geological Surveys.

The Geological Surveys of the United Kingdom are under the general direction of Sir Henry T. De la Beche, and their central office is at the Museum. In this office the maps and sections are prepared and deposited.

The Mining Record Office.

This office, superintended by Mr. Robert Hunt, was established for the preservation of Mining Records: such as plans and sections of existing mines, and of those which have been abandoned; also for collecting statistical information connected with the mining interests of the country.

Attempts attended with considerable loss of capital have frequently been made to mine in localities, in which a little knowledge would have shown there was small prospect of success. Through ignorance of old and deserted mine workings, great danger to the miner is not uncommonly incurred, and human life has been frequently sacrificed. The preservation of Mining Records has for its object the prevention of the loss of life or of property.

A large collection of plans and sections of mines, and important statistical details, are deposited in this Office. These are made available for the instruction of students, and may, at all times, under certain necessary regulations, be consulted by those who are interested in the mineral productions of the United Kingdom.

Laboratories.

Chemical Laboratory.

The general Laboratory for instruction in chemical manipulation, in qualitative and quantitative analysis, and in the method of performing chemical researches, is under the direction of Dr. Hofmann. The ROYAL COLLEGE OF CHEMISTRY has recently become the property of the Government, and its spacious and well-furnished Laboratories are now used for the instruction of the pupils of the Metropolitan School of Science applied to Mining and the Arts.

The Laboratory instruction, which is divided into a *qualitative* and *quantitative* course, is necessarily adapted to the previous knowledge of the student, such as he may have acquired by attending the chemical lectures delivered at the Institution. The course commences with experimental exercises, calculated to make the pupil *practically* acquainted with the *general* properties of the simple substances. The next subjects of his study are the *analytical* properties of the elements, and of their most important compounds. The knowledge thus acquired is subsequently put into practice in the performance of a series of analyses, so arranged as to lead the student, step by step, from

the simplest to the most complicated cases, both of qualitative and quantitative analysis. Particular attention is paid to the use of the blow-pipe, and the various methods of commercial testing, alkalimetry, chlorimetry, &c.

The fundamental studies in Practical Chemistry are the same for all pupils, however different the future pursuit may be to which the knowledge obtained will be applied. It is only after the most important methods of distinguishing, separating, and estimating substances, have been mastered, and after sufficient practice and skill in experiment have been acquired, that the course of each student diverges into some special line. This will of necessity vary with his abilities and his ultimate objects.

Each laboratory student works independently; there are no classes. All operations are superintended by the Professor and his assistants. A table with drawers, cupboard, and shelves, is appropriated to every pupil. The Institution supplies gas, fuel, and re-agents. Larger and more expensive instruments, such as air-pumps, thermometers, barometers, condensers, large evaporating dishes, &c. may be had on loan from the Laboratory. The student has to provide himself only with the apparatus specified in the Laboratory Regulations.

Metallurgical Laboratory.

This Laboratory is under the direction of Dr. Percy, and is devoted to practical instruction in Metallurgy. The nature of this instruction will be adapted to the special requirements of the student. It comprises,—

1. Assaying in all its branches, especially of the more important metals, such as iron, copper, lead, tin, alloys of silver and gold, &c.
2. Blow-pipe practice, with particular reference to *quantitative* as well as *qualitative* examinations.
3. Quantitative analyses of ores and metallurgical products. This is a very important department of practical metallurgy, and is essential to those who desire to be able to investigate the principles of any metallurgical process.

Natural History Department.

As the relative age and sequence of Geological formations are, to a great extent, determined by the evidence of Fossils, it has been found necessary in the prosecution of the Geological Survey, to establish a department of Natural History. This science, which treats of the Forms, Functions, and Habits of Living Beings, presents itself to the Geological Student under two aspects. In the first place, he must be practically acquainted with those fossils which characterize the various sedimentary rocks; but it is no less essential, secondly, that he thoroughly comprehend the general laws of Life and the physical conditions of the existence of Living Beings. The former of these objects will be obtained by a series of Demonstrations of the chief fossil forms—the latter by lectures upon the General Doctrines of Natural History.

LECTURES.

Courses of lectures on the following subjects will be given during the Session :—

Chemistry.

The course of Lectures upon Chemistry is both theoretical and practical. The general laws of chemical affinity and combination will be fully explained, both with reference to the abstract discoveries of the Science, and to their practical applications. The first part of the lectures embraces Inorganic Chemistry, and will treat of the chemical history of the more important mineral substances and their uses in the arts and manufactures. Among the technical subjects specially considered, and which will be introduced systematically in the course, may be mentioned,—the conditions of water-supply for domestic purposes; purification of water; artificial mineral waters; phosphorus, and the manufacture of lucifer and other matches; the manufacture of sulphuric acid; potash and its salts; nitrate of potash, nitric acid, gunpowder, chlorate of potash; soda salts; technology of common salt, hydrochloric acid, sulphate of soda, carbonate of soda, &c.; borax and boracic acid; lime-salts; bleaching powder; mortars and cements; glass and pottery;

manufacture of alum; salts of the metals, sulphates of iron, copper, &c.; fuel; gas, and products of distillation of coal, &c.

Organic Chemistry, which forms the second part of the course will be treated in the same manner. Among the technical subjects introduced under this head may be mentioned,—wood, peat; starch, sugar, and gums; fermented liquors; organic colouring matters; bleaching, dyeing, and printing of textile materials; leather; oils, vegetable and animal, and their products, as candles, soap, &c.; ammoniacal salts; prussiates of potash and Prussian blue; gelatine, &c.; animal black, &c.

Metallurgy.

The course of instruction in Metallurgy consists of lectures and laboratory practice. The lectures embrace the following subjects:—

- I. General considerations on the nature of metallurgical processes.
- II. On fuel. Estimation and comparison of the calorific power of various kinds of fuel.
- III. On the materials used in the construction of furnaces and metallurgical apparatus. Fire-clay, &c. Manufacture of fire-bricks, crucibles, &c.
- IV. Special metallurgical processes.
 - a. Copper-smelting; causes of the varieties of copper.
 - b. Extraction of zinc from its ores. Brass and preparation of calamine brass. Various alloys of copper and zinc used in the arts; dipping, lacquering, and bronzing.
 - c. Lead-smelting. Refining and de-silverizing. Treatment of argentiferous copper.
 - d. Smelting of silver ores. Amalgamation by the American and Freiberg processes; other methods of extracting silver from its ores.
 - e. Treatment of gold ores. Methods of parting gold and silver on the large scale. Alloys of gold and silver for monetary and other purposes. Modes of assaying, with special reference to standards of common occurrence.

- f.* Extraction of mercury by various methods.
- g.* Extraction of antimony from its ores. Alloys of antimony; type metal, &c.
- h.* Extraction of bismuth from its ores.
- i.* Extraction of nickel from its ores. Production of German silver.
- k.* Treatment of cobalt ores. Manufacture of zaffre, and cobalt colours. Analysis of ores containing nickel and cobalt.
- l.* Preparation of metallic arsenic and its compounds used in the arts, as arsenious acid, &c.
- m.* Preparation and smelting of tin ores.
- n.* Smelting and manufacture of iron. Steel.
- o.* Preparation of the metals of rarer application in the arts, as cadmium, uranium, platinum, palladium, iridium.

V. The principles and practice of electro-metallurgy.

The object of the lectures is the communication of such instruction as the student may be able to apply to the greatest practical advantage, when he may be subsequently engaged in conducting any metallurgical process.

Geology.

This course includes, first, a detailed account of the geological processes now in action on the surface and in the interior of the earth, as far as they are understood. This embraces the proofs of the origin of stratified rocks, resulting from degradation of the land, produced by the action of rain, rivers, frost, glaciers, icebergs, &c. The nature of marine denudation (the destruction of land by the sea) is explained. In connexion with these subjects, the transport of matter mechanically and in solution by rivers, the formation of deltas, &c., and the general accumulation of great deposits of marine and freshwater strata are examined. The theory of salt lakes is considered. Also, the proofs that large areas of the earth's surface are now being slowly elevated above, or depressed beneath the sea. The connexion of coral reefs and of earthquake and volcanic phenomena with this subject is fully discussed, and the analogies traced between existing

volcanic phenomena and those of past geological periods. The relation of these subjects to the mode of occurrence of organic remains in the rocks, and of the consolidation of strata generally, forms a branch of this part of the subject. An account of the more important substances entering into the composition of rocks is also given, together with an explanation of geological terms, &c.

The second part of the course includes a descriptive account of the whole series of geological formations, showing their stratigraphical order, manner of deposition, the general nature of their organic remains, and the igneous rocks with which they are occasionally associated. The origin and distribution of coal and of the useful metals, of rock-salt, &c., come under this part of the course. The laws by which questions connected with these and other important subjects are determinable are explained, together with the connexion of Geology with questions bearing on physical geography.

An account is also given of the use of instruments and of the mode of conducting geological surveys, and of the economic bearings of the subject generally.

General Natural History.

This subject includes two principal branches :—

1. The structure, functions and leading varieties of form of living beings: Biology, including Physiology and Zoology.
2. The relations of life to physical conditions: Geographical and Palæontological Distribution.

Each of these branches will be treated of in a special course of twenty-four lectures.

1st Course.—Biology.

- a. Physiology.*—The characteristic peculiarities of living beings in general; their essential functions; and the organs which perform those functions.

- b. General Morphology.*—The leading plans of form (or archetypes) presented by living beings, and resulting from the mode of arrangement of the organs.
- c. Special Morphology or Zoology.*—The chief modifications of the various common plans as exhibited in the leading orders and genera.

2d Course.—*Distribution of living beings.*

- a.* The distribution of life under existing conditions of the earth's surface.
- b.* The distribution of life under past conditions.

Full opportunity of obtaining acquaintance with special fossil forms, which is of so much importance to the geological student, will be afforded by means of regular demonstrations.

Mineralogy.

The lectures, which will be illustrated by specimens intended for close inspection, comprise:—

I. Crystallography, an introduction to this science, showing the leading classification of the crystalline forms, the laws by which their variations are determined, and their combinations, all considered with reference to the forms actually met with among crystallised substances.

II. The physical properties of minerals, treated principally with a view to the practical discrimination of the various species.

III. The elements of the chemistry of Mineralogy, with the use of the blow-pipe, and of such tests as are calculated to be serviceable to the miner, the geologist, the scientific traveller, or the general observer when in the field.

IV. The physiography or systematic description of minerals, including all the more important species and varieties, with particular reference to the mode and places of occurrence, both for those substances which bear a commercial value, and for those which derive their chief interest from geological and physical considerations.

Mining.

I. Detailed discussion of known facts connected with the deposits of the useful minerals; beds, strata, or seams; stream-works; lodes or mineral veins; flats; pipe-veins; stock-works; irregular masses; dislocations, and rules for searching for the dislocated and lost portion of a deposit.

II. Preliminary research, shoothing, trenching, costeaning.

III. Boring, as practised with different apparatus, with rods or rope, with various cutting and clearing implements.

IV. Tools employed in mining, in hard and in soft ground; in collieries and in metallic mines; blasting by various methods.

V. Principles of employment of mining labour.

VI. Modes of gaining access to, and lighting subterraneous cavities, including a comparison of the various safety lamps.

VII. Levels and shafts, or the main openings to underground works; driving and sinking.

VIII. Means of securing excavations by timbering, masonry, and tubbing; construction of dams.

IX. Exploitation, or the working away of veins and of strata.

X. Carriage or transport of minerals through the underground roads.

XI. Winding or raising in the shafts, with the machinery and apparatus required.

XII. Pumps and pumping engines.

XIII. Ventilation, its principles and practice; natural ventilation; artificial introduction of a moving power; distribution of air through the workings.

XIV. The mechanical preparation or dressing of ores.

Physics.

The principles of statics and dynamics, balances, projectiles, pendulums, &c.; hydrostatics and pneumatics; hydrostatic press, diving bell, barometers, &c.; optics; decomposition of light; optical instruments; absorption; polarization; undulatory theory; chemical, &c. effects of rays of different refrangibility; conduction and radiation of heat; specific and latent

heat; frictional electricity; Leyden jar, lightning conductors; Voltaic electricity; magnetism; terrestrial magnetism; electro-magnetism, electric telegraph, &c.

Applied Mechanics.

Principles of mechanism and mechanics, with their practical applications; friction; elasticity; strength of materials, &c.; regulators of velocity and dynamometers; steam engines, and other moving powers; general construction, arrangement, and framing of machines, and forms of their individual parts.

Machines considered with respect to their purposes; as, for direct use; or for the manufacture of spun, woven, and other similar fabrics; of metals, including mining machinery; of various vegetable and animal substances, &c. &c.

Fixed structures, as arches, roofs, &c.

Mechanical Drawing.

Instruction will be given in mechanical drawing, to enable the student to make correct drawings from apparatus and machinery, and to prepare the working drawings requisite for the guidance of the founder, smith, carpenter, and others in the construction of engines, engine-houses, machinery, and apparatus in general.

Evening Lectures.

Intimations having been made that extended courses of lectures on certain subjects, to be delivered in the evening, at moderate cost, would be of very great advantage to many persons unable to avail themselves, as occasional Students, of the regular courses of lectures given in the morning, it is intended to commence such courses during the present session.

The first will be a course of twenty lectures on the Chemistry of Non-metallic bodies, by Dr. Hofmann, of which, as of a proposed course of lectures on the Structure and Habits of living Beings, by Mr. Huxley, further notice will be given.

Lectures to Working Men.

Short courses of lectures at suitable periods of the year are given in the evening to Working Men. These courses are systematic, and arranged so as to illustrate, within the period of two years, the principal subjects taught at the Institution. Those for the ensuing Session include—

Applied Mechanics.

Geology.

Natural History.

Plan of Instruction.

It has been found that a student cannot advantageously devote equal attention to all the sciences taught in the School, and experience has shown that several classes of students attend its courses; viz., those who desire to pursue scientific studies without reference to a preparation for any special branch of industry; those who propose to become Miners or Metallurgists; and those who are to engage in Manufactures, whether chiefly depending on chemical or on mechanical principles. For these classes a scheme of instruction is proposed in the following plans, which are recommended for adoption, although they are not compulsory, since variations may be necessary in particular cases.

The divisions of study are as follows:—

- A. MINING DIVISION, for students who intend to pursue Mining.
- B. METALLURGICAL DIVISION for Students who intend to pursue Metallurgy.

C. TECHNICAL DIVISION, for those who propose to engage in other arts or manufactures depending either chiefly on Chemical, or chiefly on Mechanical Principles.

The students entering these Divisions are required to follow the course of study prescribed in the following plan:—

1st YEAR.

FOR ALL DIVISIONS.

1st TERM.	2d TERM.	3d TERM.
<i>Oct., Nov., Dec.</i>	<i>Jan., Feb., March.</i>	<i>April, May, June.</i>
Chemistry.	Chemistry.	Chemistry.
Mineralogy.	Laboratory Practice.	Laboratory Practice.
Physics.	Physics.	Natural History (2d Course).
Natural History (1st Course).		

2d YEAR.

A. MINING DIVISION.

1st TERM.	2d TERM.	3d TERM.
Mechanical Drawing.	Applied Mechanics.	Applied Mechanics.
	Mining.	Mining.
	Geology.	

2d YEAR.

B. METALLURGICAL DIVISION.

1st TERM.	2d TERM.	3d TERM.
Metallurgy, with Practice in Laboratory.	Metallurgy, with Practice in Laboratory.	Practice in Laboratory.
Mechanical Drawing.	Applied Mechanics.	Applied Mechanics.
	Geology.	

2d YEAR.

C. TECHNICAL DIVISION.

1st TERM.	2d TERM.	3d TERM.
Chemical	Chemical	Laboratory Practice.
Laboratory Practice.	Laboratory Practice.	Applied Mechanics.
Mechanical Drawing.	Applied Mechanics.	
	Geology.	

Exhibitions.

There are various Exhibitions attached to the School, some of them being general,—open to all pupils; the others being special, and connected with particular Provincial Schools.

I.—*H.R.H. The Duke of Cornwall's Exhibition.*

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, at the end of the first Session. It is held by the successful competitor for two years.

II. *Board of Trade Exhibitions.*

An exhibition of twenty-five pounds per annum will be given by the Board of Trade to the Matriculated Student who shall stand second on the list of those who have passed their examinations for the first year, and two Exhibitions for those pupils who pass the best examinations after the end of the second year. The latter Exhibitions entitle the students holding them to receive back *fifteen pounds* of the payments they have made for the Second Course of Lectures.

III. *Provincial Exhibitions.*

The Department of Science and Art provides Scholarships to certain of the Provincial Schools in connexion with the Metropolitan School of Science applied to Mining and the Arts.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of passing through the two years course of study and eventually obtaining the Certificate of the Institution, must be a

least 16 years of age, and will be required to furnish certificates, or other evidence, of their having received a sufficient preliminary education. The study of the elements of algebra and geometry, as well as the practice of drawing, are particularly recommended to those who propose to enter the School.

THE FEE for MATRICULATED STUDENTS is *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures. The Matriculated Students have the privilege of competing for the Duke of Cornwall's and other Exhibitions, and of obtaining the Certificate of the Institution; they have also constant access to the Library and Museum.

The charge for instruction in the Chemical and Metallurgical Laboratories (which is not included in the above) is *ten pounds* for the Term of three months. The Laboratories are open to Occasional as well as Matriculated Students.

OCCASIONAL STUDENTS will be admitted to the Lectures on payment of *four pounds* for each Course of forty or more Lectures, of *three pounds* for the Course of thirty and under forty, and *two pounds* for the Course under thirty.

PUPIL TEACHERS from Training Schools recommended by the Committee of Privy Council for Education, by the Board of Trade, or producing certificates satisfactory to the Director, may attend the Lectures gratuitously, provided that they be examined for at least one Course, paying a fee for such examination at the rate of from *one pound* to *two pounds* per course, according to regulations.

PERPETUAL TICKETS are issued, which entitle the holder to attend all the Courses of Lectures, upon payment of *forty pounds*.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, in the Queen's or the Honourable East India Company's Service, are admitted on similar terms.

The Session will commence, and the Chemical and Metallurgical Laboratories will open for Students on Monday, the 2d day of October, 1854.

Particulars respecting the times of Lectures, and other information, may be obtained by application to Mr. TRENHAM REEKS, Registrar, at the School, Museum of Practical Geology, Jermyn-street, London.

LIST OF GEOLOGICAL MAPS AND SECTIONS OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM,

PUBLISHED BY MESSRS. LONGMAN & Co. FOR HER MAJESTY'S STATIONERY OFFICE.

THE Maps are those of the Ordnance Survey, Geologically Coloured by the Geological Survey of Great Britain and Ireland, under the Superintendence of Sir HENRY DE LA BECHE, C.B., Director-General. The various Formations are traced and coloured in all their Subdivisions.

GREAT BRITAIN:—The Counties of which the Geological Survey is completed, are—

- BRECKNOCKSHIRE, Sheets 36, 41, 42, 56 (NW & SW), 57 (NE & SE). Sheets, 2*l.* 0*s.* 6*d.*
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 46 SW. [Part of Radnor, Brecon, and Carmarthen.] 3*s.*
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 60 SE. [Part of Montgomery, Radnor, and Shropshire.] 3*s.*
 61 NW. [Part of Shropshire.] 2*s.* 6*d.*
 61 NE. [Part of Shropshire and Staffordshire.] 3*s.*
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 74 SW. [Part of Montgomery, Denbigh, and Merioneth.] 3*s.*
 74 SE. [Part of Shropshire, Montgomery, and Denbigh.] 3*s.*
 75 NW. [Part of Caernarvon.] 2*s.*
 75 NE. [Part of Caernarvon, Merioneth, and Denbigh.] 3*s.* 6*d.*
 75 SW. [Part of Caernarvon.] 2*s.*
 75 SE. [Part of Merioneth.] 3*s.* 6*d.*
 76 N. [Part of Caernarvon.] 1*s.*
 76 S. [Part of Caernarvon.] 1*s.* 6*d.*
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Do. DUBLIN, do. 7s.	

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Horizontal Sections to WICKLOW, 4 Sheets.
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FIGURES and DESCRIPTIONS of the PALÆOZOIC FOSSILS in the above Counties. By PROFESSOR PHILLIPS
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Wicklow and Wexford. By WARINGTON W. SMYTH, M.A., &c. Vol. I. Part IV. Statistics of the Production
Tin, Lead, and Silver from the Mines of the United Kingdom, with the Exports and Imports of these
1848 to 1852 inclusive. By ROBERT HUNT, F.R.S., Keeper of Mining Records.

These Maps, Sections, and Books may be obtained at the Geological Survey Office,
Museum of Practical Geology, Jermyn-street, London.

BOARD OF TRADE.

Department of Science and Art.

PROSPECTUS

OF THE

METROPOLITAN SCHOOL OF SCIENCE

APPLIED TO

MINING AND THE ARTS.

5th Session. 1855-56.



LONDON:

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FOR HER MAJESTY'S STATIONERY OFFICE.

1855.



has long been felt in the mining districts of this kingdom. The Government School, established in connexion with the Museum of Practical Geology, in consequence of these memorials, was opened in 1851.

The courses of instruction at the School of Science applied to Mining and the Arts in Jermyn-street are conducted by the following officers :—

DIRECTOR.—Sir RODERICK IMPEY MURCHISON, D.C.L., M.A., F.R.S., &c.	
CHEMISTRY, with special reference to its applica- tions in the Arts and Manufactures	} A. W. Hofmann, Ph.D., F.R.S.
GENERAL NATURAL HISTORY	- T. H. Huxley, F.R.S.
PHYSICS	- George G. Stokes, M.A., F.R.S.
APPLIED MECHANICS,	- Robert Willis, M.A., F.R.S.
METALLURGY	- John Percy, M.D., F.R.S.
GEOLOGY	- A. C. Ramsay, F.R.S.
MINING,	} Warrington W. Smyth, M.A.,
MINERALOGY,	

REGISTRAR.—TRENHAM REEKS.

The chief object and distinctive character of this Institution (to which everything else is made subsidiary) is to give a practical direction to the course of scientific study. Although the education provided in it, will not of itself qualify the student to undertake the direction of mining and other technical operations, yet the knowledge which he may acquire of the principles of the Sciences on which the Arts are respectively based, will, in combination with future training, render him in the highest degree competent, not only to engage in any special branch of industry, but to promote its further development.

The mode of instruction is by Lectures, by written and oral Examinations, by practical teaching in the Laboratories and Drawing Office, and also by Field Surveying and Excursions, under certain conditions.

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The Geological Survey of the United Kingdom being carried on in connexion with the Museum, extensive collections are formed, illustrating the structure of the British islands and the applications of Geology to the useful purposes of life. These

collections include several series of igneous rocks arranged lithologically; of stratified rocks, arranged partly in order of superposition and partly with reference to their mode of accumulation, and their subsequent modifications; of fossils, classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances, used in the construction of public works and buildings, and of those employed for ornamental purposes, or for chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are illustrated, and examples of the results are displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiarities of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of mining in different districts. To these will be added, from time to time, models and specimens of machinery and tools for general purposes.

The Museum is and has been open to the Public for the first three days of the week, and, at the beginning of next year, when the catalogues now in progress shall have been prepared, it is intended to extend this time to five days in the week of gratuitous admission, with the exception of one month of vacation, from the 10th of August to the 10th of September.

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The Geological Surveys of the United Kingdom are under the general direction of Sir Roderick Impey Murchison, and their central office is at the Museum. In this office the maps and sections are prepared and deposited, and may be purchased by the public here, or at Messrs. Longman and Co.'s. (See the cover for a list of prices.)

The Mining Record Office.

Considerable loss of capital has frequently resulted from attempts to mine in localities, where a little knowledge of what had been previously done would have shown there was small prospect of success. Through ignorance of old and deserted mine workings, great danger to the miner is not uncommonly incurred, and human life has been frequently sacrificed. The preservation of Mining Records has for its object the prevention of such loss of life and of property.

A large collection of plans and sections of mines, and important statistical details, are deposited in this Office, under the superintendence of Mr. Robert Hunt. They are made available for the instruction of students, and may, at all times, under certain regulations, be consulted by those who are interested in the mineral productions of the United Kingdom.

Laboratories.

Chemical Laboratory.

The general Laboratory for instruction in chemical manipulation, in qualitative and quantitative analysis, and in the method of performing chemical researches, is under the direction of Dr. Hofmann. The ROYAL COLLEGE OF CHEMISTRY having become the property of the Government, its spacious and well-furnished Laboratories are used for the instruction of the pupils of the Metropolitan School of Science applied to Mining and the Arts.

The Laboratory instruction, which is divided into a *qualitative* and *quantitative* course, is necessarily adapted to the previous knowledge of the student, such as he may have acquired by attending the chemical lectures delivered at the Institution. The course commences with experimental exercises, calculated to make the pupil *practically* acquainted with the *general* properties of the simple substances. The next subjects of his study are the *analytical* properties of the elements, and of

their most important compounds. The knowledge thus acquired is subsequently put into practice in the performance of a series of analyses, so arranged as to lead the student, step by step, from the simplest to the most complicated cases, both of qualitative and quantitative analysis. Particular attention is paid to the use of the blow-pipe, and the various methods of commercial testing, alkalimetry, chlorimetry, &c.

The fundamental studies in Practical Chemistry are the same for all pupils, however different the future pursuit may be to which the knowledge obtained will be applied. It is only after the most important methods of distinguishing, separating, and estimating substances, have been mastered, and after sufficient practice and skill in experiment have been acquired, that the course of each student diverges into some special line. This will of necessity vary with his abilities and his ultimate objects.

Each laboratory student works independently; there are no classes. All operations are superintended by the Professor and his assistants. A table with drawers, cupboard, and shelves, is appropriated to every pupil. The Institution supplies gas, fuel, and re-agents. Larger and more expensive instruments, such as air-pumps, thermometers, barometers, condensers, large evaporating dishes, &c. may be had on loan from the Laboratory. The student has to provide himself only with the apparatus specified in the Laboratory Regulations.

Metallurgical Laboratory.

This Laboratory is under the direction of Dr. Percy, and is devoted to practical instruction in Metallurgy. The nature of this instruction will be adapted to the special requirements of the student. It comprises,—

Assaying in all its branches, especially of the more important metals, such as iron, copper, lead, tin, alloys of silver and gold, &c.; and the examination of ores and metallurgical products.

Natural History Department.

As the relative age and sequence of Geological formations are, to a great extent, determined by the evidence of Fossils, it has been found necessary in the prosecution of the Geological Survey, to establish a department of Natural History. This science, which treats of the Forms, Functions, and Habits of Living Beings, presents itself to the Geological Student under two aspects. In the first place, he must be practically acquainted with those fossils which characterize the various sedimentary rocks; but it is no less essential, secondly, that he thoroughly comprehend the general laws of Life and the physical conditions of the existence of Living Beings. The former of these objects will be obtained by a series of Demonstrations of the chief fossil forms—the latter by lectures upon the General Doctrines of Natural History.

LECTURES.

Courses of lectures on the following subjects will be given during the Session :—

Chemistry.

The course of Lectures upon Chemistry is both theoretical and practical. The general laws of chemical affinity and combination will be fully explained, both with reference to the abstract discoveries of the Science, and to their practical applications. The first part of the lectures embraces Inorganic Chemistry, and will treat of the chemical history of the more important mineral substances and their uses in the arts and manufactures. Among the technical subjects specially considered, and which will be introduced systematically in the course, may be mentioned,—the conditions of water-supply for domestic purposes; purification of water; artificial mineral waters; phosphorus, and the manufacture of lucifer and other matches; the manufacture of sulphuric acid; potash and its salts; nitrate of potash, nitric acid, gunpowder, chlorate of potash, soda salts; technology of common salt, hydrochloric acid, sulphate of soda, carbonate of soda, &c.; borax and boracic acid; lime-salts; bleaching powder; mortars and cements; glass and pottery;

manufacture of alum; salts of the metals, sulphates of iron, copper, &c; fuel; gas, and products of distillation of coal, &c.

Organic Chemistry, which forms the second part of the course, will be treated in the same manner. Among the technical subjects introduced under this head may be mentioned,—wood, peat; starch, sugar, and gums; fermented liquors; organic colouring matters; bleaching, dyeing, and printing of textile materials; leather; oils, vegetable and animal, and their products, as candles, soap, &c.; ammoniacal salts; prussiates of potash and Prussian blue; gelatine, &c.; animal black, &c.

Metallurgy.

The course of instruction in Metallurgy consists of lectures and laboratory practice. The lectures embrace the following subjects:—

- I. General considerations on the nature of metallurgical processes.
- II. On fuel. Estimation and comparison of the calorific power of various kinds of fuel.
- III On the materials used in the construction of furnaces and metallurgical apparatus. Fire-clay, &c. Manufacture of fire-bricks, crucibles, &c.
- IV. Special metallurgical processes.
 - a. Copper-smelting; causes of the varieties of copper.
 - b. Extraction of zinc from its ores. Brass and preparation of calamine brass. Various alloys of copper and zinc used in the arts; dipping, lacquering, and bronzing.
 - c. Lead-smelting. Refining and de-silverizing. Treatment of argentiferous copper.
 - d. Smelting of silver ores. Amalgamation by the American and Freiberg processes; other methods of extracting silver from its ores.
 - e. Treatment of gold ores. Methods of parting gold and silver on the large scale. Alloys of gold and silver for monetary and other purposes. Modes of assaying, with special reference to standards of common occurrence.

- f. Extraction of mercury by various methods.
- g. Extraction of antimony from its ores. Alloys of antimony; type metal, &c.
- h. Extraction of bismuth from its ores.
- i. Extraction of nickel from its ores. Production of German silver.
- k. Treatment of cobalt ores. Manufacture of zaffre, and cobalt colours. Analysis of ores containing nickel and cobalt.
- l. Preparation of metallic arsenic and its compounds used in the arts, as arsenious acid, &c.
- m. Preparation and smelting of tin ores.
- n. Smelting and manufacture of iron. Steel.
- o. Preparation of the metals of rarer application in the arts, as cadmium, uranium, platinum, palladium, iridium.

The object of the lectures is the communication of such instruction as the student may be able to apply to the greatest practical advantage, when he may be subsequently engaged in conducting any metallurgical process.

Geology.

This course includes, first, a detailed account of all known geological processes now in action on the surface and in the interior of the earth. It embraces the proofs of the origin of stratified rocks, resulting from degradation of the land, produced by the action of rain, rivers, frost, glaciers, icebergs, &c. The nature of aqueous denudation, including the destruction of land by the sea, is explained. In connexion with these subjects, the transport of matter by rivers, both mechanically and in solution, the formation of deltas, &c., and the general accumulation of great deposits of marine and freshwater strata are examined. The theory of the origin of salt lakes is considered; also, the proofs that large areas of the earth's surface are now being slowly elevated above, or depressed beneath the sea. The relations of coral reefs and of earthquake and volcanic phenomena to this branch of the subject are fully discussed, and the analogies between existing volcanic phenomena and those

of past geological periods are traced. The mode of occurrence of organic remains in the rocks, and the consolidation of strata form other branches of this division of the course. An account of the more important mineral substances entering into the composition of rocks is also given, together with an explanation of geological terms, &c.

The second part of the course includes a description of the whole series of geological formations, showing their stratigraphical order, manner of deposition, the general nature of their organic remains, and of the igneous rocks with which they are occasionally associated; the origin and distribution of coal and of the useful metals, of rock-salt, &c. The laws by which questions connected with these and other important subjects are determinable are explained, as well as the connexion of Geology with Physical geography.

An account is also given of the use of instruments and of the mode of conducting geological surveys, and of the economic bearings of the subject.

General Natural History.

This subject includes two principal branches :—

1. The structure, functions and leading varieties of form of living beings: Biology, including Physiology and Zoology.
2. The relations of life to physical conditions: Geographical and Palæontological Distribution.

These branches will be treated of in a course of fifty lectures in the following order :—

- a. *Physiology*.—The characteristic peculiarities of living beings in general; their essential functions; and the organs which perform those functions.
- b. *General Morphology*.—The leading plans of form (or archetypes) presented by living beings, and resulting from the mode of arrangement of the organs.
- c. *Special Morphology or Zoology*.—The chief modifications of the various common plans as exhibited in the leading orders and genera.

d. The distribution of life under existing conditions of the earth's surface.

e. The distribution of life under past conditions.

Full opportunity of obtaining acquaintance with special fossil forms, which is of so much importance to the geological student, will be afforded by means of regular demonstrations.

Mineralogy.

The lectures, which will be illustrated by specimens intended for close inspection, comprise:—

I. Crystallography, an introduction to this science, showing the leading classification of the crystalline forms, the laws by which their variations are determined, and their combinations, all considered with reference to the forms actually met with among crystallised substances.

II. The physical properties of minerals, treated principally with a view to the practical discrimination of the various species.

III. The elements of the chemistry of Mineralogy, with the use of the blow-pipe, and of such tests as are calculated to be serviceable to the miner, the geologist, the scientific traveller, or the general observer when in the field.

IV. The physiography or systematic description of minerals, including all the more important species and varieties, with particular reference to the mode and places of occurrence, both for those substances which bear a commercial value, and for those which derive their chief interest from geological and physical considerations.

Mining.

I. Detailed discussion of known facts connected with the deposits of the useful minerals; beds, strata, or seams; stream-works; lodes or mineral veins; flats; pipe-veins; stock-works; irregular masses; dislocations, and rules for searching for the dislocated and lost portion of a deposit.

- II. Preliminary research, shoading, trenching, costeaning.
- III. Boring, as practised with different apparatus, with rods or rope, with various cutting and clearing implements.
- IV. Tools employed in mining, in hard and in soft ground; in collieries and in metallic mines; blasting by various methods.
- V. Principles of employment of mining labour.
- VI. Modes of gaining access to, and lighting subterraneous cavities, including a comparison of the various safety lamps.
- VII. Levels and shafts, or the main openings to underground works; driving and sinking.
- VIII. Means of securing excavations by timbering, masonry, and tubbing; construction of dams.
- IX. Exploitation, or the working away of veins and of strata.
- X. Carriage or transport of minerals through the underground roads.
- XI. Winding or raising in the shafts, with the machinery and apparatus required.
- XII. Pumps and pumping engines.
- XIII. Ventilation, its principles and practice; natural ventilation; artificial introduction of a moving power; distribution of air through the workings.
- XIV. The mechanical preparation or dressing of ores.

Physics.

The principles of statics and dynamics, balances, projectiles, pendulums, &c.; hydrostatics and pneumatics; hydrostatic press, diving bell, barometers, &c.; optics; decomposition of light; optical instruments; absorption; polarization; undulatory theory; chemical, &c. effects of rays of different refrangibility; conduction and radiation of heat; specific and latent heat; frictional electricity; Leyden jar, lightning conductors; Voltaic electricity; magnetism; terrestrial magnetism; electro-magnetism, electric telegraph, &c.

Applied Mechanics.

Principles of mechanism and mechanics, with their practical applications ; friction ; elasticity ; strength of materials, &c. ; regulators of velocity and dynamometers ; steam engines, and other moving powers ; general construction, arrangement, and framing of machines, and forms of their individual parts.

Machines considered with respect to their purposes ; as, for direct use ; or for the manufacture of spun, woven, and other similar fabrics ; of metals, including mining machinery ; of various vegetable and animal substances, &c. &c.

Fixed structures, as arches, roofs, &c.

Mechanical Drawing.

Instruction will be given in mechanical drawing, to enable the student to make correct drawings from apparatus and machinery, and to prepare the working drawings requisite for the guidance of the founder, smith, carpenter, and others in the construction of engines, engine-houses, machinery, and apparatus in general.

Lectures to Working Men.

Short courses of lectures at suitable periods of the year are given in the evening to Working Men. These courses are systematic, and arranged so as to illustrate, within the period of two years, the principal subjects taught at the Institution. Those for the ensuing Session include—

Chemistry.
Metallurgy.

Physics.
Mineralogy.

Plan of Instruction.

It has been found that a student cannot advantageously devote equal attention to all the sciences taught in the School, and experience has shown that several classes of students attend its courses; viz., those who desire to pursue scientific studies without reference to a preparation for any special branch of industry; those who propose to become Miners or Metallurgists; and those who are to engage in Manufactures, whether chiefly depending on chemical or on mechanical principles. For these classes a scheme of instruction is proposed in the following plans, which are recommended for adoption, although they are not compulsory, since variations may be necessary in particular cases.

The divisions of study are as follows:—

- A. MINING DIVISION**, for students who intend to pursue Mining.
- B. METALLURGICAL DIVISION** for Students who intend to pursue Metallurgy.
- C. TECHNICAL DIVISION**, for those who propose to engage in other arts or manufactures depending either chiefly on Chemical, or chiefly on Mechanical Principles.

The students entering these Divisions are required to follow the course of study prescribed in the following plan:—

1st YEAR.

FOR ALL DIVISIONS.

1st TERM.

Oct., Nov., Dec., Jan., part of Feb.

Chemistry.

Physics.

Laboratory Practice.

2d TERM.

Part of Feb., Mar., April, May, June.

Natural History.

Mineralogy.

Laboratory Practice.

2d YEAR.

A. MINING DIVISION.

1st TERM.

Mining.

Mechanical Drawing.

2d TERM.

Applied Mechanics.

Geology.

2d YEAR.

B. METALLURGICAL DIVISION.

1st TERM.

Metallurgy, with Prac-
tice in Laboratory.
Mechanical Drawing.

2d TERM.

Applied Mechanics.
Geology.
Practice in Metallurgical
Laboratory.

2d YEAR.

C. TECHNICAL DIVISION.

1st TERM.

Chemical
Laboratory Practice.
Mechanical Drawing.

2d TERM.

Chemical
Laboratory Practice.
Applied Mechanics.
Geology.

Exhibitions.

There are various Exhibitions attached to the School, some of them being general,—open to all pupils; the others being special, and connected with particular Provincial Schools.

I.—*H.R.H. The Duke of Cornwall's Exhibition.*

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, at the end of the first Session. It is held by the successful competitor for two years.

II. *Board of Trade Exhibitions.*

An exhibition of twenty-five pounds per annum will be given by the Board of Trade to the Matriculated Student who shall stand second on the list of those who have passed their examinations for the first year, and two Exhibitions for those pupils who pass the best examinations after the end of the second year. The latter Exhibitions entitle the students holding them to receive back *fifteen pounds* of the payments they have made for the Second Course of Lectures.

III. *Provincial Exhibitions.*

The Department of Science and Art provides Scholarships to certain of the Provincial Schools in connexion with the Metropolitan School of Science applied to Mining and the Arts.

IV. *The Edward Forbes Medal.*

The Trustees appointed by the Committee of the Edward Forbes Memorial Fund have presented to the Institution a bronze medal, to be competed for annually by Students of the second year, and to be awarded to the one who shall be found most competent to apply the knowledge he has acquired in Natural History to Palæontology and Geology.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of passing through the two years course of study and eventually obtaining the Certificate of the Institution, must be at least 16 years of age, and will be required to furnish certificates, or other evidence, of their having received a sufficient preliminary education. The study of the elements of algebra and geometry, as well as the practice of drawing, are particularly recommended to those who propose to enter the School.

THE FEE for MATRICULATED STUDENTS is *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures. The Matriculated Students have the privilege of competing for the Duke of Cornwall's and other Exhibitions, and of obtaining the Certificate of the Institution; they have also constant access to the Library and Museum.

The charge for instruction in the Chemical and Metallurgical Laboratories (which is not included in the above) is *ten pounds* for the Term of three months. The Laboratories are open to Occasional as well as Matriculated Students.

The School of Science applied to Mining and the Arts is conducted by the following officers :—

SIR RODERICK IMPEY MURCHISON, D.C.L., M.A., F.R.S., &c.—*Director.*

A. W. HOFMANN, L.L.D., F.R.S.—Lecturer on *Chemistry.*

T. H. HUXLEY, F.R.S.—Lecturer on *General Natural History.*

GEORGE G. STOKES, M.A., F.R.S.—Lecturer on *Physics.*

ROBERT WILLIS, M.A., F.R.S.—Lecturer on *Applied Mechanics.*

JOHN PERCY, M.D., F.R.S.—Lecturer on *Metallurgy.*

A. C. RAMSAY, F.R.S.—Lecturer on *Geology.*

WARINGTON W. SMYTH, M.A.—Lecturer on { *Mining.*
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TRENHAM REEKS.—*Registrar.*

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LECTURES.

Courses of lectures on the following subjects will be given during the Session:—

Chemistry.

The course of Lectures upon Chemistry is both theoretical and practical. The general laws of chemical affinity and combination will be fully explained, both with reference to the abstract discoveries of the Science, and to their practical applications. The first part of the lectures embraces Inorganic Chemistry, and will treat of the chemical history of the more important mineral substances and their uses in the arts and manufactures. Among the technical subjects specially considered, and which will be introduced systematically in the course, may be mentioned,—the conditions of water-supply for domestic purposes; purification of water; artificial mineral waters; phosphorus, and the manufacture of lucifer and other matches; the manufacture of sulphuric acid; potash and its salts; nitrate of potash, nitric acid, gunpowder, chlorate of potash, soda salts; technology of common salt,

hydrochloric acid, sulphate of soda, carbonate of soda, &c.; borax and boracic acid; lime salts; bleaching powder; mortars and cements; glass and pottery; manufacture of alum; salts of the metals, sulphates of iron, copper, &c.; fuel; gas, and products of distillation of coal, &c.

Organic Chemistry, which forms the second part of the course, will be treated in the same manner. Among the technical subjects introduced under this head may be mentioned, wood, peat; starch, sugar, and gums; fermented liquors; organic colouring matters; bleaching, dyeing, and printing of textile materials; leather; oils, vegetable and animal, and their products, as candles, soap, &c.; ammoniacal salts; prussiates of potash and Prussian blue; gelatine, &c.; animal black, &c.

Metallurgy.

The course of instruction in Metallurgy consists of lectures and laboratory practice. The lectures embrace the following subjects:—

- I. General considerations on the nature of metallurgical processes.
- II. On fuel. Estimation and comparison of the calorific power of various kinds of fuel.
- III. On the materials used in the construction of furnaces and metallurgical apparatus. Fire-clay, &c. Manufacture of fire-bricks, crucibles, &c.
- IV. Special metallurgical processes.
 - a. Copper-smelting; causes of the varieties of copper.
 - b. Extraction of zinc from its ores. Brass and preparation of calamine brass. Various alloys of copper and zinc used in the arts; dipping, lacquering, and bronzing.
 - c. Lead-smelting. Refining and de-silverizing. Treatment of argentiferous copper.
 - d. Smelting of silver ores. Amalgamation by the American and Freiberg processes; other methods of extracting silver from its ores.

- e. Treatment of gold ores. Methods of parting gold and silver on the large scale. Alloys of gold and silver for monetary and other purposes. Modes of assaying, with special reference to standards of common occurrence.
- f. Extraction of mercury by various methods.
- g. Extraction of antimony from its ores. Alloys of antimony; type metal, &c.
- h. Extraction of bismuth from its ores.
- i. Extraction of nickel from its ores. Production of German silver.
- k. Treatment of cobalt ores. Manufacture of zaffre and cobalt colours. Analysis of ores containing nickel and cobalt.
- l. Preparation of metallic arsenic and its compounds used in the arts, as arsenious acid, &c.
- m. Preparation and smelting of tin ores.
- n. Smelting and manufacture of iron. Steel.
- o. Preparation of the metals of rarer application in the arts, as cadmium, uranium, platinum, palladium, iridium.

The object of the lectures is the communication of such instruction as the student may be able to apply to the greatest practical advantage, when he may be subsequently engaged in conducting any metallurgical process.

Geology.

The first part of this course includes a detailed account of the geological processes now in action on the surface and in the interior of the earth. It embraces the proofs of the origin of stratified rocks, resulting from degradation of the land, produced by the action of rain, rivers, frost, glaciers, icebergs, &c. The nature of aqueous denudation, including the destruction of land by the sea, is explained. In connexion with these subjects, the transport of matter by rivers, both mechanically and in solution, the formation of deltas,

&c., and the general accumulation of great deposits of marine and freshwater strata are examined. The theory of the origin of salt lakes is considered; also, the proofs that large areas of the earth's surface are now being slowly elevated above, or depressed beneath the sea. The relations of coral reefs and of earthquake and volcanic phenomena to this branch of the subject are discussed, and the analogies between existing volcanic phenomena and those of past geological periods are traced. The mode of occurrence of organic remains in the rocks, and the consolidation of strata form other branches of this division of the course. An account of the more important mineral substances entering into the composition of rocks is also given, together with an explanation of geological terms, &c.

The second part includes a description of the whole series of geological formations, showing their stratigraphical order, manner of deposition, the general nature of their organic remains, and the igneous rocks with which they are occasionally associated; the origin and distribution of coal and of the useful metals, of rock-salt, &c. The laws by which questions connected with these and other important subjects are determinable are explained, as well as the connexion of Geology with Physical geography.

An account is also given of the use of instruments, of the mode of conducting geological surveys, and of the economic bearings of the subject.

General Natural History.

This subject includes two principal branches:—

1. The structure, functions and leading varieties of form of living beings: Biology, including Physiology and Zoology.
2. The relations of life to physical conditions: Geographical and Palæontological Distribution.

These branches will be treated of in a course of fifty lectures in the following order:—

- a. *Physiology*.—The characteristic peculiarities of living beings in general; their essential functions; and the organs which perform those functions.
- b. *General Morphology*.—The leading plans of form (or archetypes) presented by living beings, and resulting from the mode of arrangement of the organs.
- c. *Special Morphology or Zoology*.—The chief modifications of the various common plans as exhibited in the leading orders and genera.
- d. The distribution of life under existing conditions of the earth's surface.
- e. The distribution of life under past conditions.

Full opportunity of obtaining acquaintance with special fossil forms, which is of so much importance to the geological student, will be afforded by means of regular demonstrations in the Museum, by the Palæontologist.

Mineralogy.

The lectures, which will be illustrated by specimens intended for close inspection, comprise:—

I. Crystallography, an introduction to this science, showing the leading classification of the crystalline forms, the laws by which their variations are determined, and their combinations, all considered with reference to the forms actually met with among crystallised substances.

II. The physical properties of minerals, treated principally with a view to the practical discrimination of the various species.

III. The elements of the chemistry of Mineralogy, with the use of the blow-pipe, and of such tests as are calculated to be serviceable to the miner, the geologist, the scientific traveller, or the general observer when in the field.

IV. The physiography or systematic description of minerals, including all the more important species and varieties, with particular reference to the mode and places of occurrence, both for those substances which bear a commercial value, and for those which derive their chief interest from geological and physical considerations.

Mining.

I. Detailed discussion of known facts connected with the deposits of the useful minerals; beds, strata, or seams; stream-works; lodes or mineral veins; flats; pipe-veins; stock-works; irregular masses; dislocations, and rules for searching for the dislocated and lost portion of a deposit.

II. Preliminary research, shoothing, trenching, costeaning.

III. Boring, as practised with different apparatus, with rods or rope, with various cutting and clearing implements.

IV. Tools employed in mining, in hard and in soft ground; in collieries and in metallic mines; blasting by various methods.

V. Principles of employment of mining labour.

VI. Modes of gaining access to, and lighting subterraneous cavities, including a comparison of the various safety lamps.

VII. Levels and shafts, or the main openings to underground works; driving and sinking.

VIII. Means of securing excavations by timbering, masonry, and tubbing; construction of dams.

IX. Exploitation, or the working away of veins and of strata.

X. Carriage or transport of minerals through the underground roads.

XI. Winding or raising in the shafts, with the machinery and apparatus required.

XII. Pumps and pumping engines.

XIII. Ventilation, its principles and practice; natural ventilation; artificial introduction of a moving power; distribution of air through the workings.

XIV. The mechanical preparation or dressing of ores.

Physics.

The principles of statics and dynamics, balances, projectiles, pendulums, &c.; hydrostatics and pneumatics; hydrostatic press, diving bell, barometers, &c.; optics; decomposition of light; optical instruments; absorption; polarization; undulatory theory; chemical, &c. effects of rays of different refrangibility; conduction and radiation of heat; specific and latent heat; frictional electricity; Leyden jar, lightning conductors; Voltaic electricity; magnetism; terrestrial magnetism; electro-magnetism, electric telegraph, &c.

Applied Mechanics.

Principles of mechanism and mechanics, with their practical applications; friction; elasticity; strength of materials, &c.; regulators of velocity and dynamometers; steam-engines, and other moving powers; general construction, arrangement, and framing of machines, and forms of their individual parts.

Machine tools for working in wood or metal and various other machines for direct use.

Mechanical Drawing.

Instruction will be given in mechanical drawing, to enable the student to make correct drawings from apparatus and machinery, and to prepare the working drawings requisite for the guidance of the founder, smith, carpenter, and others in the construction of engines, engine-houses, machinery, and apparatus in general.

The examination papers for the past Session (1856-7) are appended.

Lectures to Working Men.

Short courses of lectures at suitable periods of the year are given in the evening to Working Men. These courses are systematic, and arranged so as to illustrate, within the period of two years, the principal subjects taught at the Institution. Those for the ensuing Session include—

Chemistry.
Metallurgy.

Physics.
Mining.

Evening Lectures.

During the Session a short course of Lectures on Natural History will be delivered by Professor Huxley.

Plan of Instruction.

Experience has shown that several classes of students attend the courses of the school ; viz., those who desire to pursue scientific studies without reference to preparation for any special branch of industry ; those who propose to become Miners or Metallurgists ; and those who are to engage in Manufactures, whether chiefly depending on chemical or on mechanical principles. In the following plan, which is recommended for adoption, schemes of instruction are proposed for these classes.

The divisions of study are as follows :—

- A. MINING DIVISION, for Students who intend to pursue Mining.
- B. METALLURGICAL DIVISION, for Students who intend to pursue Metallurgy.
- C. TECHNICAL DIVISION, for those who propose to engage in other arts or manufactures depending either chiefly on Chemical or chiefly on Mechanical Principles.

The courses of instruction are distributed over three years, but those Students who possess sufficient preliminary training, may, if they think fit, pass through the whole in two years, by presenting themselves at the end of the first year, for examination in the subjects allotted to the first and second years.

Matriculated Students are required to attend all the courses of the first two years, but in the third the Students entering the above Divisions may devote themselves exclusively to the Subjects respectively allotted to them.

1st YEAR.

FOR ALL DIVISIONS.

1st TERM.

Oct., Nov., Dec., Jan., part of Feb.

Chemistry.

Laboratory Practice.

2d TERM.

Part of Feb., Mar., April, May, June.

Natural History.

2nd YEAR.

FOR ALL DIVISIONS.

1st TERM.

Physics.

Mechanical Drawing.

2nd TERM.

Mineralogy.

Palæontological Demonstrations.

3rd YEAR.

A. MINING DIVISION.

1st TERM.

Mining.

Mechanical Drawing continued.

2d TERM.

Applied Mechanics.

Geology.

3rd YEAR.

B. METALLURGICAL DIVISION.

1st TERM.

Metallurgy, with Practice in Laboratory.

2d TERM.

Applied Mechanics.

Geology.

3rd YEAR.

C. TECHNICAL DIVISION.

1st TERM.

Laboratory Practice.

2d TERM.

Applied Mechanics.

Geology.

Exhibitions.

There are various Exhibitions attached to the School, some of them being general—open to all pupils; the others being special and connected with particular Provincial Schools.

I.—*H.R.H. the Duke of Cornwall's Exhibition.*

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, at the end of the second Session. It is held by the successful competitor for two years. The following is a list of the Students to whom these Exhibitions have been awarded:—

Session	1851-2	-	-	-	-	Henry Francis Blanford.*
"	"	(for one year)	-	-	-	Robert Hunt. †
"	1852-3	-	-	-	-	William Thomas Blanford. ‡
"	1853-4	-	-	-	-	Frederic Drew. §
"	1854-5	-	-	-	-	Charles Gould.
"	1855-6	-	-	-	-	John Morland.
"	1856-7	-	-	-	-	William Weston.

II.—*Government Exhibitions.*

Two Exhibitions of fifteen pounds each are given to the Matriculated Students who shall stand highest on the list of those who have passed their examinations for the first year; and an Exhibition of twenty-five pounds to that pupil who passes the best examinations after the end of the second year. These Exhibitions will be granted to those Students only who have obtained first-class places in the examinations of their year, or in those of at least two of the

* Of the Geological Survey of India.

† Mint, Sydney.

‡ Of the Geological Survey of India.

§ " " Great Britain.

|| " " "

Professors in the case of such Students as take the first two years in one. They have been awarded to the following Students:—

1855. 1st Year's Student, 25 <i>l.</i> to	- -	Ambrose Tween.
„ 2d Year's Students, 15 <i>l.</i> each to	- {	Frederic Drew. George P. Wall.*
1856. 1st Year's Students, 25 <i>l.</i> to	- {	Edward Matthey. Mark Bullen.†
„ 2d Year's Student, 15 <i>l.</i> each to	- {	Charles Gould. Ambrose Tween.
1857. 2d Year's Students, 15 <i>l.</i> each to	- {	Richard Thornton. John Morland.

III. *Provincial Exhibitions.*

The Council of the School provides Scholarships for certain Provincial Schools.

IV. *The Edward Forbes Medal.*

The Trustees appointed by the Committee of the Edward Forbes Memorial Fund have presented to the Institution a bronze medal and a prize of books, to be competed for annually by Students of the third year, and to be awarded to the one who shall be found to possess the best knowledge of Natural History and Palæontology:

Awarded in 1855 to Frederic Drew.

„ 1856 to Charles Gould.

„ 1857 to John Morland.

V. *The De la Beche Medal.*

The Council awards annually to the Matriculated Student who shall have exhibited the greatest proficiency in those subjects not included in the Edward Forbes prize, a bronze medal and prize of books, established in memory of the late director, Sir Henry de la Beche.

Awarded in 1857 to Richard Thornton.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of passing through the entire course of study and eventually obtaining the Official Certificate of the In-

* Superintendent of the Geological Survey of the West Indies.

† Omitted from the list published in the last prospectus.

stitution, must be at least 16 years of age, and will be required to furnish certificates or other evidence of their having received a sufficient preliminary education. The study of the elements of algebra and geometry, as well as the practice of drawing, are particularly recommended to those who propose to enter the School.

THE FEE for MATRICULATED STUDENTS is *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures. The Matriculated Students have the privilege of competing for the Duke of Cornwall's and other Exhibitions, and of obtaining the Certificate of the Institution; they have also constant access to the Library and Museum.

The charge for instruction in the Chemical or in the Metallurgical Laboratory (which is not included in the above) is *ten pounds* for the Term of three months. The Laboratories are open to Occasional as well as Matriculated Students.

OCCASIONAL STUDENTS will be admitted to the Lectures on payment of *two pounds* for each Course of forty or more Lectures, of *one pound ten shillings* for the Course of thirty and under forty, and *one pound* for the Course under thirty. Students desirous of obtaining certificates will be required to pass the examinations, and to pay an additional fee of *one pound* per course.

PUPIL TEACHERS from Training Schools recommended by the Committee of Privy Council on Education, or producing certificates satisfactory to the Director, may attend the Lectures gratuitously, provided that they be examined for at least one Course, paying a fee for such examination at the rate of from *one pound* to *two pounds* per course, according to regulations.

PERPETUAL TICKETS are issued, which entitle the holder always to attend the Courses of Lectures, upon payment of *forty pounds*.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, in the Queen's or the Honourable East India Company's Service, and Her Majesty's Consular and Diplomatic Officers are admitted on similar terms.

The Chemical and Metallurgical Laboratories will be opened for Students on Thursday, the 1st day of October 1857. The lectures commence on Monday the 6th October.

Further information may be obtained by application to Mr. TRENHAM REEKS, Registrar, Museum of Practical Geology, Jermyn-street, London.

EXAMINATION PAPERS

For the Session 1856-7.

EXAMINATION IN CHEMISTRY.

24th June 1857.

1. State one of the processes for the separation of cobalt and nickel.

2. Describe the method of estimating the amount of potassium and sodium when occurring together.

3. What is meant by the term the "hardness of water?" and how is the hardness of water determined for practical purposes?

4. Describe the manufacture, the chemical constitution, the properties, and the applications of chloride of lime (bleaching powder).

5. Give a short outline of the manufacture of coal gas.

6. Give a brief history of the organic bases.

7. What is the volume (expressed in cubic inches) of dry oxygen gas that can be prepared from 1000 grains of pure binoxide of manganese by means of sulphuric acid, at the temperature of 25°C , and under an atmospheric pressure of 28 inches. (100 cubic inches of dry oxygen gas at 15°C (60°F .) and 30 inches barometric pressure, weighing 34.29 grains).

The practical examination consists in the qualitative analysis of a mixture of several mineral acids and bases, of which the following are some examples:—

- | | |
|--|--|
| (1.) Sulphate of zinc.
Chloride of barium.
Phosphate of lime. | Marble, and
Chloride of mercury. |
| (2.) Chloride of barium.
Ferrocyanide of potassium.
Sulphate of copper. | (7.) Sand.
Chloride of potassium.
Chromate of potash.
Sulphate of zinc. |
| (3.) Chloride of mercury.
Red oxide of lead.
Fluoride of calcium. | (8.) Phosphate of lime.
Chloride of ammonium.
Ammonia-Alum. |
| (4.) Chloride of ammonium
Ferrocyanide of potassium.
Sulphate of copper. | (9.) Sulphate of zinc.
Oxalate of lime, and
Chloride of mercury. |
| (5.) Chromate of potash.
Oxalate of lime.
Sulphate of copper. | (10.) Ferrocyanide of potassium,
Red oxide of lead,
Sand, and
Sulphur. |
| (6.) Sulphate of baryta,
Sulphur, | |

A. W. HOFMANN.

EXAMINATION IN PHYSICS.

7th March 1857.

1. DEDUCE the principle of the parallelogram of forces from that of the lever, and show how it may be verified experimentally.

2. Describe the construction of the common balance in which the pans are supported from below, and explain the paradox connected with it.

3. Show that the centre of gravity of an uniform triangle is the same as it would be if the weight were equally divided between the angular points.

4. If a railway carriage were placed at the top of an incline of 1 in 200, one mile long, and were then left to itself, find at what rate it would be moving by the time it got to the bottom, friction, &c. being neglected.

5. A stone attached to a string 4 feet long is whirled round four times in a second; find the proportion of the tension of the string to the weight of the stone.

6. Give the expression for the time of vibration of a simple pendulum of length l .

For what objects chiefly have the times of vibration of free pendulums been observed?

7. Explain the fundamental property which characterizes fluids. Explain also the hydrostatic paradox.

8. Enunciate the principle of Archimedes, and show how it may be verified experimentally, with accuracy.

Give two methods of comparing the specific gravities of two liquids.

9. Show how Boyle's or Mariotte's law may be proved experimentally.

10. Describe the construction and action of the hydraulic ram.

11. Show how to fill and graduate a thermometer.

In the construction of a standard thermometer, show how to divide the interval between the freezing and boiling points into equal volumes. How may a thermometer be tested as to its calibration?

12. If v be the volume of a gas under the barometric pressure h , and at the temperature $t^\circ \text{C}$, V the volume which the gas would occupy under the standard pressure H , and at the temperature 0° , give the formula for deducing V from v .

What is the numerical value of the coefficient of expansion for air?

13. Define specific heat, and show how the ratio of the specific heat of such a substance as iron to that of water may be found.

14. Water sometimes sinks down to near 22° F. without freezing, but, on agitation, a portion immediately freezes, and the temperature rises to 32° : explain this.

15. Explain the circumstances on which depends the draught of a chimney. Why is a chimney more apt to smoke when the fire is first lighted? What is the use of encasing a tall chimney with a separate shell of brick-work?

16. Explain the construction of the electrophorus, and the mode of using it. How would you show experimentally that the charge which the metallic plate receives is of the opposite kind of electricity to that excited in the resinous plate?

17. In a voltaic arrangement of numerous elements, with its ends unconnected, show how the tendency for positive electricity to accumulate towards one end, and negative towards the other, may be rendered evident in experiment; and thence infer the existence of a continuous current of electricity, when the ends are connected by wires. Which end furnishes positive electricity?

18. In a single cell of Smee's battery, if the metals be connected by wires with electrodes, one of copper and one of platinum, in a glass of dilute sulphuric acid, either no sensible current passes, or a current passes freely, according as one or other of the electrodes is the copper one. Explain this.

19. Describe Oersted's experiment relative to the action of a current on a magnetic needle; and give a rule for determining the direction of the deflection.

20. Enunciate the laws of reflection and refraction of light; and explain fully the formation of images by plane mirrors.

G. G. STOKES.

EXAMINATIONS IN NATURAL HISTORY.

1.—General Natural History.

27th June 1857.

**** No Candidate will be allowed to pass unless he answer satisfactorily one question in each of the six following sections.*

§ I.

1. What is the structure of the organs of circulation and of respiration in a mammal, and how do these organs differ from those of a fish and those of a turtle?

2. In what respects do the Marsupialia differ from the placental Mammalia?

3. Of how many segments is the vertebrate skull composed; what are their relations to planes passing through the occipital foramen, the pituitary body and the anterior boundary of the cranial cavity; and of what bones is each segment composed?

§ II.

1. Of how many somites is the body of *Homarus* composed? How many enter into the head, thorax, and abdomen respectively; and how are their appendages modified?

2. How do the Insecta differ from the Crustacea in structure?

3. Define the groups Echinoida, Clypeastroida, and Spatangoida.

§ III.

1. What are the distinctive characters of the Cephalopoda?

2. Describe the different parts of the shell of *Waldheimia*.

3. To what class of the Mollusca do *Hippurites* and *Radiolites* belong?

§ IV.

1. How do *Actinia* and *Hydra* differ in structure?

2. What corals are almost exclusively palæozoic, and how are they distinguished from the corals of the tertiary and recent epochs?

3. Define the terms Theca, Septum, Palulus, Columella, Dissepimentum.

§ V.

1. What are the classes of the Protozoa, and how do they differ from one another?

2. Describe the structure of a sponge.

3. What is a *Gregarina*?

§ VI.

1. What is there remarkable in the geological and geographical distribution of *Sauromatrichia* and *Ganoidei*?

2. What orders of Reptilia are entirely mesozoic?

3. To what order do the oldest known Mammalia belong?

Give the class and order of the specimens marked 1, 2, 3, 4, 5, 6.

2.—Practical Palæontology.

Conducted by Mr. J. W. Salter.

3d July 1857.

1. Mention the earliest known organic remains, the earliest known mollusks, and the animals or plants associated with them.

2. Distinguish the Silurian (or Lower Palæozoic) rocks from the Upper, by fossil groups, and give examples of the genera.

3. Give the range of the Trilobita, and the characters of a few genera from each zone; the same of Graptolites.

4. State what the groups of Cephalopods are characteristic of or peculiar to

Lower Palæozoic

Upper Palæozoic

and

Secondary

} rocks, with examples of the genera and their leading characters.

5. Give some of the genera of corals characteristic of the Lower and Upper Palæozoic rocks, and state what orders are peculiar or characteristic in the older or newer rocks respectively.

6. State the range of the principal families of Echinodermata, and in what strata each is peculiar or abundant; with examples of the genera. Show how the Palæozoic differ from the later Echinida, and where the latter forms commence.

7. In what strata have the earliest remains of land plants been found? What are the general characters of the Flora of the coal? Name the chief families of plants found in it.

8. Distinguish by their obvious characters

Sigillaria

Cyclopteris

Lepidodendron

Adiantopteris

Calamites

Pecopteris

Neuropteris

Sphenopteris

Odontopteris

What Coniferæ are known in the coal?

What group of plants is added in the secondary rocks?

What plants abound in tertiary strata?

9. What is the general character of the coal Fauna; and what the probability of its being freshwater or otherwise?

Give the character of Anthracosia.

10. Describe specimens 1 to 8, and give the genus to which they belong and the formations in which they occur.

3.—Edward Forbes Medal and Prize.

3rd July 1857.

1.—Explain and illustrate by examples the Theory of the "Alternation of Generations."

2.—Describe the structure of a Belemnite, and give at length the evidence by which its zoological position has been determined.

3.—What is the course of the circulation in a Mammal? Enumerate the most important differences between the circulatory organs of *Amphioxus*, *Gadus*, *Accipenser*, *Rana*, *Chelone*, and *Crocodilus*?

4.—Describe the structure of *Anodon* and of *Buccinum*, and point out in what respects they differ from one another.

5.—What is an *Avicularium*?

6.—Describe the structure and developement of *Lepas*.

7.—The skull of a Crocodile is before you. Enumerate in their proper order the bones of which it is composed, and state in what respects it differs from that of a Mammal.

8.—What are the component parts of the temporal bone in a Mammal? What is the difference in the mode of suspension of the lower jaw in Mammals and Reptiles? What is Meckel's cartilage, and what becomes of it in Mammalia?

9.—What are the distinctive peculiarities of the vertebræ in the *Ophidia*?

10.—On what grounds are the *Labyrinthodonta* regarded as *Amphibia*.

Give the class and order of the specimens marked 1, 2, 3, 4, 5, 6, and state the reasons of your determination in each case.

THOMAS H. HUXLEY.

EXAMINATION IN MINERALOGY.

3d July 1857.

1. Define a rectangle, rhomb, deltoid, and prism.

2. Describe the {axial character, and the chief forms of the Oblique system of Crystallography; illustrate them by drawings of common crystals of two well known oblique substances.

3. If in the upper part of a mineral vein you find pentagonal dodecahedrons of brown colour and brown streak, and cubical

impressions containing rhombic colourless crystals with semi-adamantine lustre; what minerals are these, and what conclusions may you draw from them as to the history of the mineral vein?

4. What colours are given to a bead of borax glass by the oxides of Iron, Manganese, Copper, Titanium, Molybdenum, Nickel, Cobalt, 1st. hot, 2d. cold?

5. What are the points of resemblance and of difference between Augite and Hornblende, and what are the rocks into whose composition these minerals enter?

6. Describe physically and chemically the gems, Ruby, Spinel, Amethyst, Aquamarine.

7. What are the principal varieties of Garnet, and the difficulties, dependent on their composition, in placing them in order from a chemical point of view?

8. Describe the minerals from which zinc is obtained.

9. What are the minerals most important for their proportion of Cadmium and of Molybdenum?

10. Describe fully 6 of the most valuable ores of silver.

11. Determine 12 specimens on the table, stating anything of importance as to their association with other minerals.

12. Describe 10 models of crystals, naming in each case minerals which crystallize in those forms.

WARINGTON W. SMYTH.

EXAMINATION IN MINING.

3rd June 1857.

1. What general conclusions may be drawn as to the character of *irregular repositories of ore*, or such as can neither be classed among lodes or beds? Describe three of the most remarkable European instances.

2. Mention the chief character of the *gossans* of different lodes; under what circumstances they may be expected to occur, what minerals are contained in them, and in what manner they affect practical mining.

3. What are the *greatest depths* attained by bore-holes, coal mines, and metallic mines respectively? State whether any circumstances have been observed which at increasing depths bear upon the working of the minerals.

4. State the *price of boring* at moderate depths ; and describe the apparatus employed by Dégousée, Kind, and Von Oeynhausen for bore-holes of unusual depth.
5. Describe, with a sketch drawing, on a scale of $\frac{1}{2}$ inch to 1 foot, the timbering of a shaft as practised in Cornwall, and in the large shafts of the Hartz.
6. Describe, with similar drawing, the method of tubbing back water, with polygonal wooden tubbing, and with cast iron tubbing.
7. Illustrate the principal features of the Yorkshire method of working coal *in banks*, and of the *long wall* system ; stating what conditions are favourable to the latter.
8. What are the principles of Furnace Ventilation ? Describe the construction of a good pit furnace. Under what circumstances may a mechanical ventilator be preferred ; and what are the laws affecting the passage of air through air-ways which are chiefly to be regarded in the distribution of the ventilating current ?
9. Describe, with drawings, the arrangements of a *plunger lift*.
10. Give the details of the common *jigging machine*, and of the continuous one applied to the washing of coal ; also of the processes by which tin-stuff is prepared for the smelter.

WARINGTON W. SMYTH.

EXAMINATION IN APPLIED MECHANICS.

30th May 1857.

1. DEFINE motion, and explain its principal varieties, *e.g.* rectilinear, curvilinear, reciprocating, uniform, variable, &c.
2. What is a *skew-bevil wheel* ? and what a *Marlborough wheel* ?
3. Explain *pitch*, *pitch circles*, and the *line of centres*.
4. What is the construction and purpose of the *Geneva stop* ?
5. Explain the differential screw.
6. What is the difference between the action of the lever of Lagarousse and the common ratchet and detent ?
7. Give an example of a parallel motion.
8. Explain the variations of motions in a boiler-punch machine moved by a cam.
9. Shew the general arrangement of a saw mill.
10. What is the proportion between the power and weight in the inclined plane and in the screw.
11. Explain the fusee and spring barrel of a clock.
12. State the principal laws of friction.

ROBERT WILLIS.

EXAMINATION IN GEOLOGY.

16 May, 1857.

1. Name six of the most important substances that enter into the composition of Rocks.
2. What are the three kinds of Coral Reefs, and under what circumstances have those Coral Reefs been formed that have deep water outside?
3. Describe Mr. Hopkins's theory of the mode of the consolidation of the earth from a state of igneous fusion?
4. How would you distinguish cleavage from bedding?
5. What is meant by the metamorphism of rocks?
6. Draw a fault affecting any set of rocks (say coal measures), on which there lies unconformably newer beds which cover all the ground and are not affected by the fault?
7. Name some classes and genera of fossils, by the presence of which you would easily distinguish Silurian from Carboniferous Rocks?
8. Under what physical conditions were most of the beds of coal in any coalfield accumulated?
9. By what peculiar grouping of fossils would you distinguish Palæozoic and Secondary Rocks?
10. (Entirely omitting freshwater and estuary strata), between what British marine formations are there complete breaks in the succession of species?
11. What peculiar climatical conditions existed in Pleistocene times over what are now the temperate regions of the northern hemisphere? Give two striking proofs of this peculiarity?
12. Copy the columns of strata, and draw lines alongside the formations, showing the distribution in time, of *Lingula*, *Graptolites*, *Orthis*, *Spirifer*, *Terebratula*, *Trigonia*, *Nautilus*, *Goniatite*, *Orthoceras*, *Ammonite*, *Crioceras*, *Belemnites*, *Pinna*, *Trilobites*, *Pterodactyle*, *Ichthyosaurus*, Marsupial Animals, Elephants, Whales.

EXAMINATION IN METALLURGY.

30th June 1857.

1. In coke and charcoal-burning; state the conditions which determine the largest yield in each case.
2. State the composition of some of the chief varieties of fire-brick in common use.

The School of Mines and of Science applied to the Arts is conducted by the following officers :—

SIR RODERICK IMPEY MURCHISON, D.C.L., M.A., F.R.S., &c.—*Director.*

A. W. HOFMANN, LL.D., F.R.S.—Lecturer on *Chemistry.*

T. H. HUXLEY, F.R.S.—Lecturer on *General Natural History.*

GEORGE G. STOKES, M.A., F.R.S.—Lecturer on *Physics.*

ROBERT WILLIS, M.A., F.R.S.—Lecturer on *Applied Mechanics.*

JOHN PERCY, M.D., F.R.S.—Lecturer on *Metallurgy.*

A. C. RAMSAY, F.R.S.—Lecturer on *Geology.*

WARINGTON W. SMYTH, M.A., F.R.S.—Lecturer on $\left\{ \begin{array}{l} \text{Mining.} \\ \text{Mineralogy.} \end{array} \right.$

TRENHAM REEKS.—*Registrar.*

The chief object and distinctive character of this Institution (to which everything else is made subsidiary) is to give a practical direction to the course of scientific study. Although the education provided in it, will not of itself qualify the student to undertake the direction of mining and other technical operations, yet the knowledge which he may acquire of the principles of the Sciences on which the Arts are respectively based, will, in combination with future training, render him in the highest degree competent, not only to engage in any special branch of industry, but to promote its further development.

The mode of instruction is by Lectures, by written and oral Examinations, by practical teaching in the Laboratories and Drawing Office, and also by Field Excursions, under certain conditions.

The Museum.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum, extensive collections are formed, illustrating the structure of the British islands and the applications of Geology to the useful purposes of life. These collections include several series of igneous rocks arranged lithologically; of stratified rocks, arranged partly in order of superposition and partly with reference to their mode of accumulation, and their subsequent

modifications; of fossils, classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances, used in the construction of public works and buildings, and of those employed for ornamental purposes, or for chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are illustrated, and examples of the results are displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiarities of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of mining in different districts. To these will be added, from time to time, models and specimens of machinery and tools for general purposes.

The Museum is open gratuitously to the Public every day in the week but Friday, with the exception of one month of vacation, from the 10th of August to the 10th of September.

Geological Surveys.

The Geological Surveys of the United Kingdom are under the general direction of Sir Roderick Impey Murchison, and their central office is at the Museum. In this office the maps and sections are prepared for publication. They may be obtained here and at Messrs. Longman's, Paternoster Row. (See the cover for a list of prices.)

The Mining Record Office.

Considerable loss of capital has frequently resulted from attempts to mine in localities, where a little knowledge of what had been previously done would have shown there was

small prospect of success. Through ignorance of old and deserted mine workings, great danger to the miner is not uncommonly incurred, and human life has been frequently sacrificed. The preservation of Mining Records has for its object the prevention of such loss of life and of property.

A large collection of plans and sections of mines, and important statistical details, are deposited in this Office, under the superintendence of Mr. Robert Hunt. They are made available for the instruction of students, and may, at all times, under certain regulations, be consulted by those who are interested in the mineral productions of the United Kingdom.

Laboratories.

Chemical Laboratory.

The general Laboratory for instruction in chemical manipulation, in qualitative and quantitative analysis, and in the method of performing chemical researches, is under the direction of Dr. Hofmann. The ROYAL COLLEGE OF CHEMISTRY having become the property of the Government, its spacious and well-furnished Laboratories are used for the instruction of the pupils of the School of Mines and of Science applied to the Arts.

The Laboratory instruction, which is divided into a *qualitative* and *quantitative* course, is necessarily adapted to the previous knowledge of the student, such as he may have acquired by attending the chemical lectures delivered at the Institution. The course commences with experimental exercises, calculated to make the pupil *practically* acquainted with the *general* properties of the simple substances. The next subjects of his study are the *analytical* properties of the elements, and of their most important compounds. The knowledge thus acquired is subsequently put into practice in the performance of a series of analyses, so arranged as to lead the student, step by step, from the simplest to the

most complicated cases, both of qualitative and quantitative analysis. Particular attention is paid to the use of the blow-pipe, and the various methods of commercial testing, alkali-metry, chlorimetry, &c.

The fundamental studies in Practical Chemistry are the same for all pupils, however different the future pursuit may be to which the knowledge obtained will be applied. It is only after the most important methods of distinguishing, separating, and estimating substances, have been mastered, and after sufficient practice and skill in experiment have been acquired, that the course of each student diverges into some special line. This will of necessity vary with his abilities and his ultimate objects.

Each laboratory student works independently ; there are no classes. All operations are superintended by the Professor and his assistants. A table with drawers, cupboard, and shelves, is appropriated to every pupil. The Institution supplies gas, fuel, and re-agents. Larger and more expensive instruments, such as air-pumps, thermometers, barometers, condensers, &c., may be had on loan from the Laboratory. The student has to provide himself only with the apparatus specified in the Laboratory Regulations.

Metallurgical Laboratory.

This Laboratory is under the direction of Dr. Percy, and is devoted to practical instruction in Metallurgy. The nature of this instruction will be adapted to the special requirements of the student. It comprises,—

Assaying in all its branches, especially of the more important metals, such as iron, copper, lead, tin, alloys of silver and gold, &c. ; and the examination of ores and metallurgical products.

Natural History Department.

As the relative age and sequence of Geological formations are, to a great extent, determined by the evidence of Fossils, it has been found necessary in the prosecution of the Geological Survey, to establish a department of Natural History. This science, which treats of the Forms, Functions, and Habits of Living Beings, presents itself to the Geological Student under two aspects. In the first place, he must be practically acquainted with those fossils which characterize the various sedimentary rocks; but it is no less essential, secondly, that he thoroughly comprehend the general laws of Life and the physical conditions of the existence of Living Beings. The former of these objects will be obtained by a series of Demonstrations of the chief fossil forms—the latter by lectures upon the General Doctrines of Natural History.

LECTURES.

Courses of lectures on the following subjects will be given during the Session:—

Chemistry.

The course of Lectures upon Chemistry is both theoretical and practical. The general laws of chemical affinity and combination will be fully explained, both with reference to the abstract discoveries of the Science, and to their practical applications. The first part of the lectures embraces Inorganic Chemistry, and will treat of the chemical history of the more important mineral substances and their uses in the arts and manufactures. Among the technical subjects specially considered, and which will be introduced systematically in the course, may be mentioned,—the conditions of water-supply for domestic purposes; purification of water; phosphorus, and the manufacture of lucifer and other matches; the manufacture of sulphuric acid; potash and its salts; nitrate of potash, nitric acid, gunpowder, chlorate of potash, soda salts; technology of common salt, hydrochloric acid, sulphate of soda, carbonate of soda, &c.;

borax and boracic acid; lime salts; bleaching powder; mortars and cements; glass and pottery; manufacture of alum; salts of the metals, &c.; fuel; gas, and products of distillation of coal, &c.

Organic Chemistry, which forms the second part of the course, will be treated in the same manner. Among the technical subjects introduced under this head may be mentioned,—wood, peat; starch, sugar, and gums; fermented liquors; organic colouring matters; bleaching, dyeing, and printing of textile materials; oils, vegetable and animal, and their products, as candles, soap, &c.; ammoniacal salts; prussiates of potash and Prussian blue; gelatine, &c.; animal black, &c.

These Lectures will be delivered at the Royal College of Chemistry, Oxford Street.

Metallurgy.

The course of instruction in Metallurgy consists of lectures and laboratory practice. The lectures embrace the following subjects:—

- I. General considerations on the nature of metallurgical processes.
- II. On fuel. Estimation and comparison of the calorific power of various kinds of fuel.
- III. On the materials used in the construction of furnaces and metallurgical apparatus. Fire-clay, &c. Manufacture of fire-bricks, crucibles, &c.
- IV. Special metallurgical processes.
 - a.* Copper-smelting; causes of the varieties of copper.
 - b.* Extraction of zinc from its ores. Brass and preparation of calamine brass. Various alloys of copper and zinc used in the arts; dipping, lacquering, and bronzing.
 - c.* Lead-smelting. Refining and de-silverizing. Treatment of argentiferous copper.
 - d.* Smelting of silver ores. Amalgamation by the American and Freiberg processes; other methods of extracting silver from its ores.

- e. Treatment of gold ores. Methods of parting gold and silver on the large scale. Alloys of gold and silver for monetary and other purposes. Modes of assaying, with special reference to standards of common occurrence.
- f. Extraction of mercury by various methods.
- g. Extraction of antimony from its ores. Alloys of antimony; type metal, &c.
- h. Extraction of bismuth from its ores.
- i. Extraction of nickel from its ores. Production of German silver.
- k. Treatment of cobalt ores. Manufacture of zaffre and cobalt colours. Analysis of ores containing nickel and cobalt.
- l. Preparation of metallic arsenic and its compounds used in the arts, as arsenious acid, &c.
- m. Preparation and smelting of tin ores.
- n. Smelting and manufacture of iron. Steel.
- o. Preparation of the metals of rarer application in the arts, as cadmium, uranium, platinum, palladium, iridium.

The object of the lectures is the communication of such instruction as the student may be able to apply to the greatest practical advantage, when he may be subsequently engaged in conducting any metallurgical process.

Geology.

The first part of this course includes a detailed account of the geological processes now in action on the surface and in the interior of the earth. It embraces the proofs of the origin of stratified rocks, resulting from degradation of the land, produced by the action of rain, rivers, frost, glaciers, icebergs, &c. The nature of aqueous denudation, including the destruction of land by the sea, is explained. In connexion with these subjects, the transport of matter by rivers, both mechanically and in solution, the formation of deltas,

&c., and the general accumulation of great deposits of marine and freshwater strata are examined. The theory of the origin of salt lakes is considered; also, the proofs that large areas of the earth's surface are now being slowly elevated above, or depressed beneath the sea. The relations of coral reefs and of earthquake and volcanic phenomena to this branch of the subject are discussed, and the analogies between existing volcanic phenomena and those of past geological periods are traced. The mode of occurrence of organic remains in the rocks, and the consolidation of strata form other branches of this division of the course. An account of the more important mineral substances entering into the composition of rocks is also given, together with an explanation of geological terms, &c.

The second part includes a description of the whole series of geological formations, showing their stratigraphical order, manner of deposition, the general nature of their organic remains, and the igneous rocks with which they are occasionally associated; the origin and distribution of coal and of the useful metals, of rock-salt, &c. The laws by which questions connected with these and other important subjects are determinable are explained, as well as the connexion of Geology with Physical geography.

An account is also given of the use of instruments, of the mode of conducting geological surveys, and of the economic bearings of the subject.

General Natural History.

This subject includes two principal branches:—

1. The structure, functions and leading varieties of form of living beings: Biology, including Physiology and Zoology.
2. The relations of life to physical conditions: Geographical and Palæontological Distribution.

These branches will be treated of in a course of fifty lectures in the following order:—

- a. *Physiology*.—The characteristic peculiarities of living beings in general; their essential functions; and the organs which perform those functions.
- b. *General Morphology*.—The leading plans of form (or archetypes) presented by living beings, and resulting from the mode of arrangement of the organs.
- c. *Special Morphology or Zoology*.—The chief modifications of the various common plans as exhibited in the leading orders and genera.
- d. The distribution of life under existing conditions of the earth's surface.
- e. The distribution of life under past conditions.

Full opportunity of obtaining acquaintance with special fossil forms, which is of so much importance to the geological student, will be afforded by means of regular demonstrations in the Museum.

Mineralogy.

The lectures, which will be illustrated by specimens intended for close inspection, comprise:—

I. Crystallography, an introduction to this science, showing the leading classification of the crystalline forms, the laws by which their variations are determined, and their combinations, all considered with reference to the forms actually met with among crystallized substances.

II. The physical properties of minerals, treated principally with a view to the practical discrimination of the various species.

III. The elements of the chemistry of Mineralogy, with the use of the blow-pipe, and of such tests as are calculated to be serviceable to the miner, the geologist, the scientific traveller, or the general observer when in the field.

IV. The physiography or systematic description of minerals, including all the more important species and varieties, with particular reference to the mode and places of occurrence, both for those substances which bear a commercial value, and for those which derive their chief interest from geological and physical considerations.

Mining.

I. Detailed discussion of known facts connected with the deposits of the useful minerals; beds, strata, or seams; stream-works; lodes or mineral veins; flats; pipe-veins; stock-works; irregular masses; dislocations, and rules for searching for the dislocated and lost portion of a deposit.

II. Preliminary research, shodding, trenching, costeaning.

III. Boring, as practised with different apparatus, with rods or rope, with various cutting and clearing implements.

IV. Tools employed in mining, in hard and in soft ground; in collieries and in metallic mines; blasting by various methods.

V. Principles of employment of mining labour.

VI. Modes of gaining access to, and lighting subterraneous cavities, including a comparison of the various safety lamps.

VII. Levels and shafts, or the main openings to underground works; driving and sinking.

VIII. Means of securing excavations by timbering, masonry, and tubbing; construction of dams.

IX. Exploitation, or the working away of veins and of strata.

X. Carriage or transport of minerals through the underground roads.

XI. Winding or raising in the shafts, with the machinery and apparatus required.

XII. Pumps and pumping engines.

XIII. Ventilation, its principles and practice; natural ventilation; artificial introduction of a moving power; distribution of air through the workings.

XIV. The mechanical preparation or dressing of ores.

Physics.

The principles of statics and dynamics, with so much of their applications as is necessary to illustrate the principles; balances, pendulums, &c. considered with reference to their physical applications; hydrostatics and pneumatics; hydrostatic press, diving bell, barometers, thermometers, &c.; conduction and radiation of heat; specific and latent heat; frictional electricity; Leyden jar, lightning conductors; Voltaic electricity; magnetism; terrestrial magnetism; electro-magnetism, electric telegraph, &c.; optics; decomposition of light; absorption; polarization; undulatory theory; chemical, &c. effects of rays of different refrangibility.

Applied Mechanics.

Principles of mechanism and mechanics, with their practical applications; friction; elasticity; strength of materials, &c.; regulators of velocity and dynamometers; steam-engines, and other moving powers; general construction, arrangement, and framing of machines, and forms of their individual parts.

Machine tools for working in wood or metal and various other machines for direct use.

Mechanical Drawing.

Instruction will be given in mechanical drawing, to enable the student to make correct drawings from apparatus and machinery, and to prepare the working drawings requisite for the guidance of the founder, smith, carpenter, and others in the construction of engines, engine-houses, machinery, and apparatus in general.

The examination papers for the past Session (1858-9) are appended.

Lectures to Working Men.

Short courses of lectures at suitable periods of the year are given in the evening to Working Men. These courses are systematic, and arranged so as to illustrate, within the period of two years, the principal subjects taught at the Institution. Those for the ensuing Session include—

Chemistry.

Metallurgy.

Physics.

Plan of Instruction.

Experience has shown that several classes of students attend the courses of the school; viz., those who desire to pursue scientific studies without reference to preparation for any special branch of industry; those who propose to become Miners or Metallurgists; and those who are to engage in Manufactures, whether chiefly depending on chemical or on mechanical principles. In the following plan, which is recommended for adoption, schemes of instruction are proposed for these classes.

The divisions of study are as follows:—

- A. MINING DIVISION, for Students who intend to pursue Mining.
- B. METALLURGICAL DIVISION, for Students who intend to pursue Metallurgy.
- C. TECHNICAL DIVISION, for those who propose to engage in other arts or manufactures depending either chiefly on Chemical or chiefly on Mechanical Principles.

The courses of instruction are distributed over three years, but those Students who possess sufficient preliminary training, may, if they think fit, pass through the whole in two years, by presenting themselves at the end of the first year, for examination in the subjects allotted to the first and second years.

Matriculated Students are required to attend all the courses of the first two years, but in the third the Students entering the above Divisions may devote themselves exclusively to the Subjects respectively allotted to them.

1st YEAR.

FOR ALL DIVISIONS.

1st TERM.

Oct., Nov., Dec., Jan., part of Feb. Part of Feb., Mar., April, May, June.

Inorganic Chemistry.
Laboratory Practice.

2d TERM.

Organic Chemistry.
Natural History.
Laboratory Practice.

2nd YEAR.

FOR ALL DIVISIONS.

1st TERM.

Physics.
Mechanical Drawing.

2nd TERM.

Mineralogy.
Palæontological Demonstrations.

3rd YEAR.

A. MINING DIVISION.

1st TERM.

Mining.
Mechanical Drawing continued.

2d TERM.

Applied Mechanics.
Geology.

3rd YEAR.

B. METALLURGICAL DIVISION.

1st TERM.

Metallurgy, with Practice in Laboratory.

2d TERM.

Applied Mechanics.
Geology.
Laboratory Practice.

3rd YEAR.

C. TECHNICAL DIVISION.

1st TERM.

Laboratory Practice.

2d TERM.

Applied Mechanics.
Geology.
Laboratory Practice.

Exhibitions.

There are various Exhibitions attached to the School, some of them being general—open to all pupils; the others being special and connected with particular Provincial Schools.

I.—*H.R.H. the Duke of Cornwall's Exhibition.*

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, who have gone through the Studies of the first two Sessions. It is held by the successful competitor for two years. The following is a list of the Students to whom these Exhibitions have been awarded:—

Session 1851-2	-	-	-	-	Henry Francis Blanford. *
"	"	(for one year)	-	-	Robert Hunt. †
"	1852-3	-	-	-	William Thomas Blanford. ‡
"	1853-4	-	-	-	Frederic Drew. §
"	1854-5	-	-	-	Charles Gould.
"	1855-6	-	-	-	John Morland.
"	1856-7	-	-	-	William Weston.
"	1857-8	-	-	-	Clement Le Neve Foster.
"	1858-9	-	-	-	Thomas William Danby.

II.—*Government Exhibitions.*

Two Exhibitions of fifteen pounds each are given to the Matriculated Students who shall stand highest on the list of those who have passed their examinations for the first year; and an Exhibition of twenty-five pounds to that pupil, not being the Duke of Cornwall's Exhibitioner, who passes the best examinations after the end of the second year. These Exhibitions will be granted to those Students only who have obtained first-class places in the examinations of their year, or in those of at least two of the Professors in

* Of the Geological Survey of India.

† Mint, Sydney.

‡ Of the Geological Survey of India.

§ " " Great Britain.

|| Superintendent of the Geological Survey of Tasmania.

the case of such Students as take the first two years in one. They have been awarded to the following Students:—

1855. 1st Year's Student, 25 <i>l.</i> to	-	-	Ambrose Tween.*
„ 2d Year's Students, 15 <i>l.</i> each to	-	{	Frederic Drew.
			George P. Wall.†
1856. 1st Year's Students, 25 <i>l.</i> to	-	-	Edward Matthey.
			Mark Bullen.
„ 2d Year's Student, 15 <i>l.</i> each to	-	{	Charles Gould.
			Ambrose Tween.*
1857. 2d Year's Students, 15 <i>l.</i> each to	-	{	Richard Thornton.‡
			John Morland.
1858. 1st Year's Student, 15 <i>l.</i> to	-	-	T. W. Danby.
„ 2d Year's Student, 25 <i>l.</i> to	-	-	Ch. S. Wood.
„ 2d Year's Student, 15 <i>l.</i> to	-	-	William Weston.
1859. 1st Year's Students, 15 <i>l.</i> each to	-	{	William Hackney.
			Walter Child.

III. *Provincial Exhibitions.*

The Council of the School provides Scholarships for certain Provincial Schools.

IV. *The Edward Forbes Medal.*

The Trustees appointed by the Committee of the Edward Forbes Memorial Fund have presented to the Institution a bronze medal and a prize of books, to be competed for annually by Students of the third year, and to be awarded to the one who shall be found to possess the best knowledge of Natural History and Palæontology.

Awarded in 1855 to Frederic Drew.

„ 1856 to Charles Gould.

„ 1857 to John Morland.

„ 1858 *No Candidate.*

„ 1859 to Clement Le Neve Foster.

V. *The De la Beche Medal.*

The Council awards annually to the Matriculated Student who shall have exhibited the greatest proficiency in those subjects not included in the Edward Forbes prize, a bronze medal and prize of books, established in memory of the late director, Sir Henry de la Beche.

Awarded in 1857 to Richard Thornton.

„ 1858 to William Weston.

„ 1859 to Ch. S. Wood.

* Of the Geological Survey of India.

† Directed the Geological Survey of Trinidad.

‡ Geologist to Dr. Livingstone's Expedition.

Regulations as to Admission.

PERSONS desirous of entering as MATRICULATED STUDENTS, with a view of passing through the entire course of study and eventually obtaining the Official Certificate of the Institution, must be at least 16 years of age, and will be required to furnish certificates or other evidence of their having received a sufficient preliminary education. The study of the elements of algebra and geometry, as well as the practice of drawing, are particularly recommended to those who propose to enter the School.

THE FEE for MATRICULATED STUDENTS is *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures. The Matriculated Students have the privilege of competing for the Duke of Cornwall's and other Exhibitions, and of obtaining the Certificate of the Institution; they have also constant access to the Library and Museum.

The charge for instruction in the Chemical or in the Metallurgical Laboratory (which is not included in the above) is *ten pounds* for the Term of three months. The Laboratories are open to Occasional as well as Matriculated Students.

OCCASIONAL STUDENTS will be admitted to the Lectures on payment of *two pounds* for each Course of forty or more Lectures, of *one pound ten shillings* for the Course of thirty and under forty, and *one pound* for the Course under thirty. Students desirous of obtaining certificates will be required to pass the examinations, and to pay an additional fee of *one pound* per course.

PUPIL TEACHERS from Training Schools recommended by the Committee of Privy Council on Education, or producing certificates satisfactory to the Director, may attend the Lectures gratuitously, provided that they be examined for at least one Course, paying a fee for such examination of *one pound* per course.

PERPETUAL TICKETS are issued, which entitle the holder always to attend the Courses of Lectures, upon payment of *forty pounds*.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, and Her Majesty's Consular and Diplomatic Officers, are admitted on similar terms.

The Chemical and Metallurgical Laboratories will be opened for Students on Monday, the 3rd day of October 1859.

By order of the Secretary of State for India, the certificate of the Professor of Metallurgy is received for appointments in the Mints of India.

Further information may be obtained by application to Mr. TRENHAM REEKS, Registrar, Museum of Practical Geology, Jermyn-street, London. S.W.

EXAMINATION PAPERS

For the Session 1858-9.

EXAMINATION IN CHEMISTRY.

1. Give an outline of the manufacture of alum.
2. Describe the method of analyzing the " sulphide of ammonium precipitate."
3. Describe the process of estimating the value of manganese ores containing carbonates.
4. Name the more frequently occurring compounds which are insoluble both in water and acids ; describe the process of rendering them soluble for analysis.
5. Give an outline of the chemical history of phosphorus.
6. State briefly the relations in which alcohol, ether, acetic acid, acetic ether, and anhydrous acetic acid stand to water. Give some examples of mixed ethers and mixed anhydrous acids.
7. Describe the action of sulphur on the alkaline carbonates at a high temperature, and the deportment of the resulting products under the influence of atmospheric air and acids.
8. The analysis of a basic compound, consisting of carbon, hydrogen, and nitrogen, has furnished the following results :—
0.250 gramme of substance gave on combustion,
0.632 ,, of carbonic acid,
0.337 ,, of water.

The base forms, with hydrochloric acid and bi-chloride of platinum, a crystalline double salt.

0.500 gramme of this double salt left on ignition,
0.168 ,, of platinum.

What is the per-centage composition of the base, and what its formula ?

Give the details of calculation.

The practical examination consists in the qualitative analysis of a mixture of several mineral acids and bases, of which the following are some examples :—

1. Minium.
Sulphate of alumina.
Sulphate of ammonia.
Chloride of barium.
Phosphate of lime.
Chloride of sodium.

2. Sulphate of alumina.
Sulphate of ammonia.
Chloride of barium.
Chromate of potash.
Phosphate of soda.
3. Minium.
Oxide of copper.
Carbonate of lime.
Sulphate of potash.
Ferrocyanide of potassium.
Sulphur.

A. W. HOFMANN.

EXAMINATION IN PHYSICS.

[*N.B.—Two questions to be answered of these three.*]

1. Draw a mechanical system in which a weight is raised by a combination of the inclined plane, the single moveable pulley, and the wheel and axle ; and show that $W \times \text{space through which } W \text{ is raised} = P \times \text{space moved through in } P\text{'s direction by the point of application of } P$.
2. Define a couple, and the arm, moment, axis of a couple ; and prove the principle of the parallelogram of couples.
3. Show that the statical effect of the weight of an uniform triangle is the same as if the weight were equally divided between the three angular points.

[*Two of these three.*]

4. A body is projected with a velocity V in the direction of the uniformly accelerating force f , and in the time t describes the space S , acquiring thereby the velocity v . Assuming the formulæ for motion from rest, deduce the relations between every three of the quantities v, f, s, t .
5. Explain the meaning of the statement "action is always accompanied by an equal and opposite reaction." In the case of a ball fired from a firmly-fixed cannon, where is the reaction ?
6. Show why the sum of the masses of the particles of a body multiplied by the squares of their respective distances from an axis is called the "moment of inertia" of the body about the axis. Describe briefly the construction of Kater's pendulum, and the object attained by it.

[One of these two.]

7. Assuming the air at the sea shore to be 840 times lighter than water, and water $13\frac{1}{2}$ times lighter than mercury, what would be the height of a cliff in ascending which from the shore the mercury in a barometer sinks 0.46 inch? Why would the simple formula which does well enough for such a cliff be inaccurate for a high mountain, and what would be the character of the error introduced by its employment?

8. Give the whole process of finding the specific gravity of a salt which is soluble in water, but not in some fluid at hand.

[Two of these three.]

9. Explain the construction and action of the hydraulic ram.

10. Explain two methods of finding the expansion of gases between the freezing and boiling points, assuming Mariotte's and Gay Lussac's laws to be strictly true. Are the results obtained in these two ways in strict accordance?

11. Write down the formula giving the velocity of propagation of a long wave in a uniform canal; and give the numerical result, in miles per hour, in the case of a semicircular canal 16 feet broad.

[Two of these three.]

12. Explain fully the action of the "electrical mill," and adduce one or two phenomena corroborative of your explanation.

13. Describe one or two experiments illustrative of the nature of induction. How do you account for the attraction of an insulated unelectrified conducting body by an excited body brought very near it?

14. Describe Harris's unit jar. How would you apply it to compare the electrical capacities of two large Leyden jars?

[Two of these three.]

15. Describe the setting of a magnetic needle when carried, at some distance, round a large bar magnet in the same horizontal plane. Point out the analogous phenomenon as regards terrestrial magnetism.

16. Describe an "astatic" needle, and a "multiplier." Under what circumstances would the effect of a multiplier be little more than that of a single coil of the same size formed of the same wire?

17. How does the effect of the introduction of a voltmeter into a voltaic circuit differ from that of a mere resistance? Describe an experiment illustrating this difference.

[One of these two.]

18. Explain the mode of scrutinizing, by means of a prism, the mode of absorption of light by a coloured solution; and mention one or two of the more remarkable results in the case of metallic solutions.

19. Describe the leading features of the phenomena exhibited by solutions of salts of quinine, &c. placed in a pure spectrum; and show how some of the effects may be exhibited by the use merely of the diffused light of day.

G. G. STOKES.

EXAMINATIONS IN NATURAL HISTORY.

1.—General Natural History.

(Morning.)

1. Contrast the circulatory, respiratory, and nervous systems of a typical mollusk with those of a typical annulose animal.

2. In what senses is the term perfection of organization used? What is meant by the division of physiological labour? Illustrate your answers by examples.

3. What is the characteristic structure, and what are the functions, of the nervous system? Define the principal parts of the nervous system of a bird.

4. Describe the structure of *Actinia*. In what respect does *Actinia* agree with, and in what does it differ from, *Cyanea*?

5. Give an account of the structure of the *Brachiopoda*, pointing out in what respects they differ from the *Lamellibranchiata*, and resemble the *Polyzoa*.

6. Give the sub-kingdom, class, and order of the specimens numbered 1-6; stating the reasons for your determination.

(Afternoon.)

1. What differences does the structure of the heart present in *Teleostei*, *Ganoidei*, *Amphibia*, *Ophidia*, and *Crocodilia*?

2. Give the number, kinds, and mode of implantation of the teeth in Man. Explain the terms Aerodont, Pleurodont, Thecodont; and state what are the structural differences between dentine and bone.

3. What characters distinguish the *Pterosauria* from the other *Reptilia*? What is their geological range?

4. What are the distinctive characters of the *Crocodylia*? How do the older Mesozoic *Crocodylia* differ from the modern species?

5. Point out the most important differences which distinguish the skeleton, respiratory organs, and heart of Birds from those of Man.

6. Give the sub-kingdom, class, and order of the specimens numbered 1-6.

2.—Practical Palæontology.

Conducted by Messrs. J. W. Salter and Robert Etheridge.

1. Name any *orders* or *families* of animals or plants peculiar to Palæozoic Rocks, or absent from them, with their leading characters and examples of the genera.

2. What genera of

Cystidiæ	} are distinctive of the	{	Primordial Zone,
Graptolites			Lower Silurian,
Trilobites			Upper Silurian,
			Devonian,
			Carboniferous.

3. Give the characters of the following genera, and their range—

Spheronites.	Ogygia.
Hemicosmites.	Phacops and its sub-
Echinsencerinus.	division.
Didymograpsus.	Harpes.
Retiolites.	Homalonotus.
Paradoxides.	Brachymetopus.

4. Mention any Brachiopods distinctive of the Palæozoic subdivisions, and distinguish—

Pentamerus	from	Camarophoria,
Strophomena	„	Orthis,
Atrypa	„	Athyris,
Productus	„	Strophalosia;

and give the range of their genera.

5. Give examples *either* of—

Corals	} distinctive of the	{	Silurian,
Cephalopods			Devonian,
or			Carboniferous,
Fish			Permian.

6. What groups of plants compose the coal flora? Give the characters of the principal genera.

7. State the leading generic forms of Fish, Reptilia, Mollusca, &c. peculiar to the Triassic Period.

8. Give the classification of the *Ammonitidæ*; state the sections and *their characters*; construct a table showing the range of the chief groups through the Mesozoic Period; also give characters of—

Crioceras.

Turrulites.

Toxoceras.

Helicoceras.

Scaphites.

9. State the broad distinction between the Palæozoic and Neozoic *Echinodermata*, the divisions of the Neozoic series; name the families that constitute these, and give the characters of the following genera—

Cidaris.

Goniaster.

Marsupites.

Cyphosoma.

Salenia.

Micraster.

10. What constitutes the peculiarity of the Neozoic corals? Name the chief families; give characters of *Turbinolidæ* and *Astreidæ*, and examples from the—

Lias.

Inferior Oolite.

Coral Rag.

Chalk.

11. Name a few of the leading genera of *Mollusca* that characterize the Lias, Lower Oolite, Portland Oolite, Purbecks, and Chalk. Notice the peculiarities of the Purbeck fauna.

12. Name the fossils placed upon the table, and their formations.

3.—Edward Forbes Medal and Prize.

(Morning.)

1. Describe the structure of the principal vital phenomena manifested by *spongilla*. Point out in what respects it agrees with and in what differs from *Gregarina* and *Vorticella*.

2. What organisms take an important share in forming calcareous or other deposits in modern seas? Describe the structure of these organisms; the modes in which they accumulate; the localities in which they are most abundant; and point out what ancient deposits are similar to them.

3. Sketch the palæontological history of the *Crustacea*, and give an account of the organization of those types which are now wholly extinct.

4. What is the object of the circulation of the blood or other nutritive fluid, and how is that circulation effected in *Cœlenterata*, *Crustacea*, *Insecta*, *Ascidioidea*, *Lamellibranchiata*, *Cephalopoda*, and *Amphioxus*?

(Afternoon.)

1. Give an account of the structure, development, and palæontological history of the *Echinodermata*.

2. What are the most remarkable peculiarities presented by the vertebral column and the skull in *Amphioxus*, *Petromyzon*, *Accipenser*, *Gadus*, *Coluber*, *Chelone*, *Homo*?

3. State what are the most important facts relating to the structure, distribution, and palæontographical history of the *Crocodylia*.

4. Name as nearly as you can the ten specimens upon the table.

THOMAS H. HUXLEY.

EXAMINATION IN MINERALOGY.

1. State what constitutes a mineral species, and the nature of the difficulty in establishing a good mineralogical classification.

2. Give an outline of the methods of classification adopted by Werner and by Berzelius.

3. Define a *prism*, and describe some of the more remarkable crystals of that form observed in Calcite, Vesuvian, Barytes, and Tourmaline.

4. Describe the chief holohedral and hemihedral forms of the cubical system, denoting the mode in which they are derivable one from another.

5. Enumerate the minerals of Mohs's Scale of Hardness and Von Kobell's Scale of Fusibility.

6. What are *pseudomorphous* minerals? and into what groups may they be divided?

7. Show how the study of such pseudomorphous substances is important in an economic or commercial point of view.

8. Describe the mode of occurrence of the Zeolites, mentioning those which are sometimes found in lodes or mineral veins.

9. State the physical and chemical characters of Augite and Hornblende, in what points they chiefly differ, and of what rocks they respectively form important constituents.

10. Describe five mineral species which may be employed as *ores of lead*, and give a drawing of a characteristic crystalline form for each.

11. What are the minerals which contain Uranium, and under what circumstances are they found?

12. Mention the principal features of the different mineral species termed Calamine.

13. Describe the models of crystalline forms placed on the table.

14. Name the twelve mineral specimens placed before you, stating by what characters they are recognized.

WARINGTON W. SMYTH.

EXAMINATION IN MINING.

1. State the results of experience as to the relation between certain ores, and the course or direction of lodes, in the Cornish mining districts.

2. Describe the analogous phenomena of the mining districts of Freyberg in Saxony, the Hartz, and Hungary.

3. What relation has been observed between the occurrence of tin ore and particular rocks? Illustrate it by reference to special localities.

4. A copper lode coursing E. and W., and underlaying 60° N., is dislocated, in the western part of the workings, by a lead lode coursing N.N.E., and dipping 70° W. In which direction would you proceed to search for the dislocated lode, and for what reason?

5. Describe the construction of the "fall-piece" employed for deep boring, and the advantage of such arrangement.

6. Describe and illustrate with drawings on a scale of 1 inch to 6 feet, the mode of timbering a level when the pressure is chiefly, first, from above; secondly, from the sides; thirdly, equally from above and both sides.

7. How would you arrange the pumps in a shaft of 100 fathoms deep? Give a detailed drawing of a plunger lift, and compare its operation with the older modes of raising water in shafts.

8. What is the prevalent mode of working coal in Yorkshire? State the dimensions of the several parts of the workings, and the causes that have led to very fatal accidents by explosion.

9. What is the theory of natural ventilation? How is such ventilation enabled to air working places which lie beyond the ordinary current, and how would you proceed to ventilate efficiently a deep metalliferous mine?

10. Illustrate by a drawing the construction of an approved form of ventilating furnace.

11. Describe, with sketch, Struve's ventilator, and the *trompe* or water fall.

12. Give a description of the apparatus called *parachutes* or safety cages.

13. What is the nature of the apparatus termed "jigging machines" and "separators" in the dressing of metallic ores, and how is an analogous machine applied to the washing of coal?

14. Describe in detail the construction of a "stamps," mentioning especially the weight of heads employed for different ores, and the mode of providing for the exit of the stamped material. State what ought to be observed with respect to speed, height of stroke, and fineness of grain, to ensure the most advantageous results.

WARINGTON W. SMYTH.

EXAMINATION IN APPLIED MECHANICS.

1. In a common grinding machine driven by the foot, describe the motion required by the power; explain that which is required by the working part, and show the arrangement by which the one is converted into the other.

2. What are the three classes of mechanical organs that constitute a machine?

3. What are the different heads under which the communication of motion from one piece in a train of mechanism to the next piece are classed?

4. Describe the arrangement of common ratchet work.

5. What prevents a rope from untwisting itself?

6. State the principal laws of friction.

7. What are the principal heads under which steam engines are classed, and by what principles are they characterized?

8. What is meant by a train of change wheels? Quote a machine in which such a train is employed, and describe the most convenient arrangement.

9. By what mechanism is the spring of a clock or watch made to exercise a constant force during the motion of the machine?

10. How is the upper extremity of a piston rod guided in a rectilinear path? Describe the arrangement of one of the parallel motions that is used for this purpose.

11. What is meant by the expansion principle in a steam engine?

12. To what practical purpose are the curves termed epicycloids and involutes applied in machinery, and how are they simply drawn upon paper?

ROBERT WILLIS.

EXAMINATION IN GEOLOGY.

1. What are the constituent minerals of granite, syenite, greenstone, and gneiss?
2. Describe the accompanying specimens of rocks.
3. State the general features of Mr. Hopkins' theory of the consolidation of the earth from a state of igneous fusion.
4. State the difference between Mallet's theory of earthquake motion and Mitchell's.
5. How would you estimate the amount of sediment carried annually to sea by a great river?
6. Define dip, strike, fault, and contortion of strata.
7. Draw a diagram showing some of the general relations of cleavage and stratification.
8. How is it known that some large areas of the earth's surface are at present being elevated above the sea, and others depressed beneath it?
9. Construct a column of the English formations, and note alongside the prominent lithological character of each.
10. Draw lines alongside the column showing the range in time of the following:—
 Lingula, Graptolites, Trilobites, Orthis, Productus, Nautilus,
 Ammonite, Cetacea, Marsupial Mammals, Ichthyosaurus,
 Rhinoceros.
11. State the chief unconformations of strata, and complete breaks in the succession of fossils in the British strata.
12. State some broad characteristics of fossil genera, by which you might distinguish Secondary from Palæozoic rocks, and Tertiary rocks from Secondary.
13. Explain the origin of coal.
14. Draw a diagram of the manner in which coal measures are sometimes concealed by unconformable Secondary rocks.
15. What are the proofs of any peculiarity of climate during part of the newer Pliocene epoch?

ANDREW C. RAMSAY.

EXAMINATION IN METALLURGY.

1. Give a classification of the various kinds of fuel employed in metallurgical processes.
2. What is meant by the term unit of heat?
3. Enumerate the chief materials which have been employed in the manufacture of crucibles.
4. Describe a reverberatory furnace, and illustrate the description by sketches.
5. Describe the method of extracting zinc by the Belgian process.
6. State the methods of refining copper.
7. Give the reactions which occur in the production of chloride of silver in Augustin's process.
8. How would you determine the proportion of silver in argentiferous alloys containing tin and gold?
9. State the theory of the production of smalts from arsenical cobalt ores containing nickel and iron.
10. How much sulphide of lead would be theoretically required to reduce a mixture of forty parts of sulphate of lead and sixty of litharge?
11. Describe the furnaces employed in lead smelting.
12. How would you assay an ore of mercury containing cinnabar and metallic mercury?
13. State the composition of the various commercial alloys containing zinc.
14. Describe the nature and varieties of pig-iron.
15. Describe the process of converting pig-iron into charcoal plates as practised in South Wales.
16. Enumerate the various kinds of iron ores which are smelted in this country, and state their composition.
17. Describe any one foreign method of converting pig into bar iron without the puddling furnace.
18. State the conditions which tend to produce "red shortness" in iron.
19. What is the average composition of the waste gases of an ordinary English blast furnace worked with coke?
20. Name the specimens placed on the table. They were, 1. Brass; 2. Nickel speiss; 3. Bronze; 4. Blue metal; 5. Speculum metal; 6. Run lead slag.

JOHN PERCY.
